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# A COMPANION TO BYZANTINE SCIENCE



*Edited by*

STAVROS LAZARIS

BRILL

A Companion to Byzantine Science

# Brill's Companions to the Byzantine World

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Cover illustration: This illustration is only found in Par. gr. 2381 (f. 78v). The "Man in the Moon" refers to a number of pareidolic images of the human face, head or body that certain traditions recognise on the face of the (full) moon. These images combine the dark areas of the lunar maria, or "seas," and the lighter highlands of the lunar surface. The "Man in the Moon" illustration is particularly interesting because the author drew it on the basis of his own observation using a mirror (ὡς ἡμεῖς διά τινος κατόπτρου τοῦθ᾽οὕτωσὶ γινόμενον ἔγνωμεν)


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Ἐπειδὴ σοφία ἐστὶν ἐπιστήμη τῆς ἐν τοῖς οὖσιν ἀληθείας, ἐπιστήμη μέν ἐστι κατάληψις τοῦ ὑποκειμένου ἄπταιστος καὶ ἀμετακίνητος, αὕτη δὲ ἡ κατάληψις οὐ δύναται ἄπταιστος καὶ ἀμετακίνητος εἶναι, εἰ μὴ τὰ ὑποκείμενα ταύτῃ τὰ αὐτὰ καὶ ὡσαύτως ἔχοντα ἀεὶ διατελοῦσι·

• • •

Wisdom is science of the truth in existing things, science is the infallible and unchanging apprehension of the subject; but this apprehension cannot be infallible and unchanging unless its objects themselves are also invariably disposed in the same way.

GEORGE PACHYMERES, *Quadrivium,* 1,2
(ed. Stephanou/Tannery; transl. [modified] Bydén, p. 286)

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# Contents

# Acknowledgments

There is always some satisfaction involved in the transformation of ideas, even vague ones at first, into models and applying these in the analysis of ancient works. The medievalist Jurgis Baltušaitis wrote: “I only have one method: go to the sources, search for the real texts beyond commentaries and studies. It is only by returning to the source that we can achieve an exact vision of the issues involved. We follow a well-trodden path but in the end, we discover a rather different landscape.” None of the authors in this volume, who proceeded according to this *modus operandi*, wished to remain on the “Regensburg platform.” This was how Vassily Kandinsky referred to travellers wishing to go to Berlin and having arrived in Regensburg thought they had already reached their destination when in truth they had only completed one leg of their journey. Every researcher who took part in this publication, chose, as much as possible, to push the boundaries of their subject and, starting from a different premise, enlighten readers on aspects of Byzantine science that were until now little known or even shunned.

Now that I have almost reached my own destination as editor of this volume, I would like to thank first of all the many colleagues who trusted me in this adventure: Fabio Acerbi, Anne-Laurence Caudano, Gonzalo Andreotti Cruz, Katerina Ierodiakonou, Hervé Inglebert, Divna Manolova, Maria K. Papathanassiou, Inmaculada Pérez Martín, Thomas Salmon, Ioannis Telelis, Alain Touwaide, Arnaud Zucker. I would also like to express my gratitude to Anne Tihon, who agreed to write the conclusion of this volume. I wish to thank very warmly Antonio Ricciardetto, who drafted this volume’s indices, as well as Julien Cahour and Romain Girardi for their excellent work in the preparation of the bibliography.

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Finally, all my gratitude goes to my wife whose tireless support was a constant encouragement and a precious help, a haven of patience that gave me the necessary strength to reach the end of this editorial and scientific enterprise.

# Figures

# Notes on Contributors

*Fabio Acerbi*
is chargé de recherche at the CNRS. He specializes in editing and studying Greek and Byzantine mathematical and astronomical texts.

*Anne-Laurence Caudano*
(PhD Cantab., 2005) is Professor of Medieval History at the University of Winnipeg. Her recent work focuses on Late Byzantine and Slavic cosmographical texts, maps and diagrams, as well as on the astronomical miscellanies of John Chortasmenos.

*Gonzalo Cruz Andreotti*
is Professor in Ancient history at the University of Málaga, where he also obtained his doctorate and held a research fellowship. He expanded his studies at the universities of Roma Tor Vergata-Roma II and Perugia, both in Italy, and at the University of the Basque Country in Spain. He currently studies different, yet closely related topics: ancient geographical thought, Iberian geography, ancient ethnic identities in Hispania—in particular concerning Turdetania—and more specifically, concrete studies on authors, such as Polybius, Strabo and Pliny.

*Katerina Ierodiakonou*
is Professor of Ancient Philosophy at the University of Athens and at the University of Geneva. She has published extensively on ancient and Byzantine philosophy, especially in the areas of epistemology and logic. She is currently working on a monograph about ancient theories of colour, as well as on an edition, translation, and commentary of Theophrastus' *De sensibus* and of Michael Psellos' paraphrase of Aristotle's *De interpretatione*.

*Hervé Inglebert*
is Professor of Roman History at Université Paris Nanterre, where he specialises in the cultural and religious developments that occurred during Late Antiquity. On these themes he has published three books, an atlas and dozens of articles, and organised and edited several symposia. He has been both a junior and senior member of the Institut universitaire de France. He has spoken at many conferences and given lectures in Europe, North America and Asia (China, Japan). He edits the international "Revue de l'Antiquité tardive" and the "Nouvelle Clio" history collection at the PUF (Presses

Universitaires de France). Inglebert also takes an interest in the epistemology of the human and social sciences, as well as the historiography of universal history, on which he has written two books: *Le Monde, l'Histoire. Essai sur les histoires universelles* (2014) and *Histoire universelle ou histoire globale ?* (2018). Between 2016–18 he was co-director of a research project on the theme "Universal histories and universal museums" with Sandra Kemp (Victoria & Albert Museum) and André Delpuech (Musée du Quai Branly).

*Stavros Lazaris*
is chargé de recherche at the CNRS and former General Secretary of the Laboratory of Excellence "Religions and Societies in the Mediterranean World (RESMED)". His research and teaching concerns the history of Byzantine civilization, including the study of original documents related to the history of science and technology. Since his doctoral thesis (published by Brepols in the "Bibliologia" collection in 2010), he has worked on medieval illustrations and their place in the transmission of medical and scientific knowledge to Byzantium. Horses and their role in the army and the economy of Late Antiquity and Byzantium is another major theme of his research. He has also written on visual cultures and, since his habilitation (published by SISMEL in the "Micrologus' Library" collection in 2016), he is interested in the Christianization of pagan scientific literature.

*Divna Manolova*
is Postdoctoral fellow at the Centre for Medieval Literature (University of Southern Denmark and University of York) where she is developing a monograph on spatiality, aesthetics and wonder in Byzantine cosmological texts and diagrams. She has published on Nikephoros Gregoras' philosophical and astronomical thought and on Byzantine epistolography more generally and is currently co-editing a volume on Byzantine commentaries on ancient texts (with B. van den Berg and P. Marciniak). Divna obtained her PhD in Medieval Studies at Central European University (2014) and was a Marie Skłodowska-Curie/POLONEZ 1 fellow at the University of Silesia in Katowice (2016–2018).

*Maria K. Papathanassiou*
is Professor *Emerita* at the Department of Mathematics at the University of Athens. She specializes in Greek and Byzantine Science (Mathematics, Astronomy, Archaeoastronomy) and Occult Sciences (Astrology, Alchemy). She focuses her research on the personality of Stephanos of Alexandria

studying his lectures *On the Great and sacred art of chrysopoeia,* of which critical edition recently published, and the astrological treatise on the Horoscope of Islam attributed to him, on which subjects she published several articles. Her recent publications also include articles on Archaeoastronomy, as the "Reflections on the Antikythera mechanism inscriptions," *Advances in Space Research,* 46 (2010), pp. 545–551.

*Inmaculada Pérez Martín*
is Scientific Researcher at the Institute of Mediterranean and Oriental Languages and Cultures, CSIC-Madrid. She is specializing in Byzantine Cultural History, Transfer of scientific knowledge in Byzantium, Greek Paleography, Transmission of Classical Texts in Byzantium, Edition of Byzantine texts.

*Antonio Ricciardetto*
concluded his PhD in Languages and Literature at the University of Liège in 2015 with a dissertation on Greek documentary papyri of medical content. After having been a research and teaching assistant at the Collège de France (2016–2018), he is currently a postdoctoral researcher at the Paris-Sciences-et-Lettres Research University, within the Interdisciplinary and Strategic Research Initiative "Scripta-PSL. The History and Practices of Writing" (2018–2019). Carrying research in the fields of papyrology and history of medicine, he is a statutory member of the centre "Byzantine Civilization" (UMR 8167 Orient & Méditerranée), a member of the CEDOPAL of the University of Liège and the secretary of the Belgian Society of Byzantine Studies. He is the author of *L'Anonyme de Londres* (P.Lit.Lond. *165,* Brit.Libr. *inv. 137*). *Édition et traduction d'un papyrus médical grec du Ier siècle apr. J.-C.* (Liège, 2014; Paris, 2016), and the co-editor of the volume *En marge du* Serment *hippocratique : contrats et serments dans le monde gréco-romain. Actes de la Journée d'étude internationale. Liège, 29 octobre 2014* (Liège, 2017).

*Thomas Salmon*
is PhD candidate at Sorbonne-Université. He is also part of the "Byzantine World" research team of the UMR 8167 Orient & Méditerranée (CNRS) and received a grant from the French Ministry of the Armed Forces. He currently studies Byzantine cavalry warfare, linking the relationship between the soldier and the horse in the Byzantine world. He also works on the archaeology of weapons and horse equipment and their representations in Byzantine art.

*Ioannis Telelis*
is Senior Researcher at the Research Centre for Greek and Latin Literature, Academy of Athens, Greece. He specialises in critical editions of Byzantine texts on natural philosophy, and his recent publications include: *Georgios Pachymeres, Philosophia. Book 5. Commentary in Aristotle's Meteorologica. Editio princeps*. Prolegomena-Text-Indices, Athens 2012; *Georgios Pachymeres, Philosophia. Book 3. In Aristotelis de Caelo Commentary. Editio princeps*. Prolegomena-Text-Indices, Athens 2016.

*Anne Tihon*
is Professeur *Emerita* of the Université Catholique de Louvain, Louvain-la-Neuve, Belgium. She taught Byzantine History and Civilization, Byzantine Texts, History of Science in Antiquity, Greek palaeography, Methodology of edition of Ancient Texts. She provided critical editions of the commentaries of Theon of Alexandria in Ptolemy's *Handy Tables* and several editions of Byzantine astronomical texts; with Jean-Luc Fournet, the edition and analysis of the astronomical papyrus P. Fouad inv. 267A. She is Director of the Corpus des Astronomes Byzantins. She is working on a critical edition of Ptolemy's *Handy Tables.*

*Alain Touwaide*
is a Classicist, a Byzantinist, and an Arabist, Alain Touwaide specializes in the History of Medicine and the Life Sciences. He has had an unconventional transdisciplinary career spent in Medical Schools, Colleges of Pharmacy, and Faculties of Sciences. After 15 years at the Natural History Museum of the Smithsonian Institution in Washington, DC (USA), he is now affiliated with the University of California Los Angeles (UCLA) (USA), where he is the Program Director of the Medical Humanities and Ethnobotany Initiative. He has taught and lectured all over the world and has authored numerous publications with a particular interest in the making of medical and life-sciences knowledge and its transmission across the Mediterranean World from Antiquity to the Renaissance and later.

*Arnaud Zucker*
is Professor of ancient Greek language and literature, at the University of Nice Côte d'Azur (FR), and deputy director of Cepam (UMR 7264, CNRS). His key research topics are ancient zoology, ancient astronomy, and mythography. He published numerous papers on the transmission of zoological knowledge and is leading the international research network *Zoomathia*. He published *Les classes zoologiques en Grèce ancienne d'Homère à Élien* (2005), *Aristote et les*

*classifications zoologiques* (2015) and translated in French Aelian's *Natura Animalium* and the *Physiologos*. He is currently working (edition and commentary) on the zoological encyclopaedia of Constantine VII. He recently published *L'encyclopédie du ciel. Mythologie, astronomie, astrologie* (Paris, 2016) and *Lire les mythes. Formes, usages et visées des pratiques mythographiques de l'Antiquité à la* Renaissance (A. Zucker, J. Fabre-Serris, J.-Y. Tilliette, G.Besson [eds.], Lille, 2016)

# Introduction

*Stavros Lazaris*

This volume is the result of a two-year collaboration between thirteen scholars of Byzantium focussing on scientific disciplines between the fourth and the fifteenth centuries. Regardless of the complexities of the various scientific fields and approaches taken by each researcher in his or her chapter, the common thread that binds this collective effort is the necessity to correct two general misconceptions about the nature of the scientific contribution of Byzantium. Indeed, for a long time, the general consensus among Byzantine specialists was that Byzantine scholars did not produce innovative scientific contributions. However, many authors in this volume, often basing their work on unpublished materials or approaches, demonstrate the opposite. To this day many historians of science still believe that science only emerged in the modern era, thus denying Byzantine production any scientific value. This misconception is due to the way in which they understand the Middles Ages and their use of the term "science." Both need to be clarified for each period under scrutiny and recontextualised.

## 1 Current Debates in the History of Science

### 1.1 *The Traditional Narrative of the History of Science, from the Greeks to the Byzantines*

Science as rational thought was born in the archaic age, in the seventh century BCE under the impetus of several thinkers and philosophers, some focussing on cosmology or physical speculation while others were religious leaders. From this period onwards, Greek science began to develop in Ionian cities such as Miletus, Chios and Samos. For some Ionian thinkers natural phenomena could be explained by natural causes, which led to the first scientific demonstrations ever produced. Thales (625–547 BCE), Anaximenes (585–525 BCE), Pythagoras (570–480 BCE) or Heraclitus (550–480 BCE) proceeded intellectually by a process of confronting arguments and contributed, each in his own way, to the birth of mathematics, astronomy and musical theory.

In the wake of these precursors, Greek thought eventually grew up around several schools. Some of these were contemporary, others developed in close succession over three productive centuries in a relatively restricted geographical area; from this arose the first scientific controversies and historical markers. However, it is only with Aristotle that science acquired a method based on

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deduction. To him we owe the first formulation of syllogisms and induction. Concepts such as material, shape and action became the first elements of abstract thought. For Aristotle, science was subordinated to philosophy (it was a "secondary" philosophy)[1] and its aim was to search for first principles and first causes that scientific discourse would later call causality, and philosophy would call Aristotelianism.

Before he founded the Lyceum, Aristotle was entrusted by Philip II with the education of his son Alexander (the Great). After the latter's death, his immense empire was shared out between his generals. Egypt, which was ruled by Alexander from 332, went to Ptolemy Soter who took the title of king and founded the Ptolemaic dynasty. The new Egyptian dynasty was primarily Greek: it marked the end of two centuries of Persian influence over the country and ended permanently the reign of indigenous Pharaohs. It strove to restore Egypt's greatness in a world that was now Greek. This period is marked by significant discoveries, especially in astronomy, mathematics and the medical sciences. For many scholars, this unprecedented development of Greek science is bound to the Ptolemies' cultural agenda. They designed and built the great library of Alexandria and bequeathed generous funds to ensure that it would become an essential centre of learning in the Hellenistic world. The library was already conceived in the early planning of the city and became the main instrument of influence of Ptolemaic Egypt. It is estimated that by 48 BCE, it contained up to 700,000 papyrus rolls.[2] The Ptolemies strongly supported and contributed to both the library and the *Museum* that was connected to it. Not only did these two institutions preserve a wealth of knowledge, but they were also a vibrant space for all the great thinkers and scholars of the Hellenistic world.[3]

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1 On the First and second philosophy in Aristotle's works, see Mansion, "Philosophie première, philosophie seconde et métaphysique chez Aristote."

2 See, for example, Gille, *Les mécaniciens grecs : la naissance de la technologie*, p. 56.

3 There is an abundant literature on Greek science in antiquity. See (chronologically) e.g. Schuhl, *Essai sur la formation de la pensée grecque*; Farrington, *Science in antiquity*; Lloyd, *Early Greek science: Thales to Aristotle*; Lloyd, *Greek science after Aristotle*; Pedersen/Pihl, *Early physics and astronomy: a historical introduction*; Lloyd, *Origines et développement de la science grecque magie, raison et expérience*; Clagett, *Greek science in antiquity*; Asper (ed.), *Writing science: medical and mathematical authorship in ancient Greece*; Kalogeropoulos, *Η ιστορία της Ελλάδας των τεχνών, των επιστημών και της τεχνολογίας στην Αρχαιότητα*; Colvin, *A brief history of ancient Greek*; Guichard/García Alonso/Paz de Hoz (eds.), *The Alexandrian Tradition. Interactions between Science, Religion, and Literature*; Michaelides/Androutsos (eds.), *Medicine and Healing in the Ancient Mediterranean world;* Stampolidis/Tasoulas, "Ἴασις. Υγεία, Νόσος, Θεραπεία από τον Όμηρο στον Γαληνό"; Holmes/Fischer (eds.), *The Frontiers of Ancient Science*; Berrey, *Hellenistic Science at Court*; König/Woolf (eds.), *Authority and Expertise in Ancient Scientific Culture*; Taub, *Science Writing in Greco-Roman Antiquity*.

Thereafter, Alexandria became the capital of a Roman province, and lived through the vicissitudes of the Roman and Byzantine empires, until the ancient capital of the Ptolemies was seized by the Arabs, led by Amr ibn Al-Asi, lieutenant of the caliph Omar. For six centuries between the fall of the Ptolemaic dynasty (31 BCE) and the Arab conquest (December 22, 640), Alexandria pursued its vocation to be a major scientific research centre, including medical research. However, little by little, through the prism of Christianity and a new society that emerged from profound socio-cultural changes, the scientific knowledge produced in this mythical city and throughout the Mediterranean world, would never be quite the same. Numerous epistemologists identify a decline in scientific production in the centuries that followed. These same researchers also believe that the only scientific contribution of the Byzantines was to have preserved the knowledge of their ancestors and transmitted it directly or indirectly to the West. K. Vogel, in his monograph on Byzantine science concedes that "Byzantium is important in the history of science" but then goes on to say: "not because any appreciable additions were made to the knowledge already attained by the Greeks of the Hellenistic era, but because the Byzantines preserved the solid foundations laid in antiquity until such time as the Westerners had at their disposal other means of recovering this knowledge."[4] Preserving this knowledge was undoubtedly a sacred cause for the Byzantines and they often copied manuscripts solely to preserve scientific literature. Generally, the Byzantines saw books as the guardians of their civilization, since the knowledge of their ancestors was recorded in their pages. That knowledge had to be protected by copying new manuscripts, so that thereafter the fate of their books became one of their major concerns.[5]

But does this mean preservation was their only contribution to science? This is a crucial question for if we answer in the affirmative, it might undermine the very rationale for yet another book on the topic.

## 1.2 *Criticisms of Byzantine Science*

### 1.2.1 Was There a "Science" Prior to Galileo?

Before we consider several approaches and offer some answers, let us ask another question, related to the first and just as important: is there such a thing

4 Vogel, "Byzantine Science," p. 264.

5 "Tell me, I pray thee, how will the world end?" Epiphanios asked St. Andrew the Fool, his master, adding: "Which signs will tell us that the time is fulfilled, and what will come of this city, the New Jerusalem? [What will happen to the] books?" (Εἰπέ μοι, παρακαλῶ σε, πῶς τὸ τέλος τοῦ κόσμου τούτου; […] ἀπὸ ποίων δὲ σημείων ἡ ἀπόδειξις ἔσται τῆς συντελείας, καὶ ποῦ παρελεύσεται ἡ πόλις ἡμῶν αὕτη ἡ νέα Ἱερουσαλήμ […] καὶ αἱ βίβλοι […]), Nikephoros Presbyter, *The Life of St Andrew the Fool*, ed./transl. Rydén, pp. 259–60 (l. 3808–13).

as science in the period we are interested in? In other words, can the Byzantine production in fields as diverse as astronomy, mathematics, medicine, botany, zoology or alchemy and astrology be characterized as scientific? According to several modern scholars, defining this production during the Middle Ages raises a number of problems, starting with the method that was followed by Byzantine scholars.

Since the "Galilean revolution" science is characterised by the combination of three requirements:[6]

1. Science is a "reality," whichever interpretation philosophers confer on the term.
2. Science seeks an "explanation," i.e. the insertion of reality that it describes in an abstract system of concepts, overflowing with singular facts brought about by experimentation.[7]
3. Science complies with criteria of "validity" that are explicitly formulated and consensual.

For many specialists, there was no science before the existence of technical means of observation for accurate measurements, the exclusive reliance on observation or experimentation (thus excluding philosophical and religious aspects or qualitative physics) in the argumentation, the formulation of laws in mathematical language forming the basis of confirmable predictions and the existence of a structured sociology of scholars.[8] Of course, based on such a configuration, the Byzantine approach to research cannot be considered to be scientific, at least not as we know it through the published preserved texts and what we know of their scholarly societies. There is no indication that the requirements mentioned above were ever applied in full, persistently and by a large body of scholars.

However in varying degrees, this was also the case in Antiquity and the Western and Arab-Muslim Middle Ages, until the early Renaissance. Indeed, and without wishing to generalize, for the medieval scholar, heir to Aristotelian

6 Modern science is the product of a long and successful transformation in Europe, over four centuries from the time of Galileo. It has given our society a method of studying nature and a new vision of the relationship between man and his Universe, in other words, "modernity." The explanation of natural phenomena in mechanical, physical or chemical terms, and their mathematical representation are the foundations of this "modernity" which contributes to the birth, in the eighteenth century, of the Industrial Age.

7 The assumption with such an explanation is that the facts one wishes to explain are first transposed in the form of an abstract "model," the elements of which can be defined by their mutual relations and, for some of them, by a relationship protocol with experimentation.

8 See also Rossi, *La nascita della scienza moderna in Europa*.

epistemology, what was scientific was logically demonstrable.[9] The experimental approach was in its infancy and very ambiguous. Even in medicine, where—as was often repeated after Galen—experience and reasoning are "the two legs" on which the medical arts rest (ἔστι γὰρ ἐν τῇ ἰατρικῇ ὡς δύο σκέλη, ἐμπειρία τε καὶ λόγος) the notion of experience (which includes experience and experimentation) is understood in two ways: either as an empirical process of trial and error, or as an experiment conducted systematically, but with unreliable results because it is subject to variations that are difficult to explain rationally.

Let us point out from the start that to apply to Byzantine culture the criteria listed above with the aim of excluding the possible existence of scientific thought processes is foolish. It reveals a fundamental ignorance and misunderstanding of the ways in which the Byzantines thought and functioned. One cannot pretend to understand a past culture without a rigorous historical approach and that culture must be measured using its own units of measurement. In A. Gourevitch's words, the idea that human nature and particularly human psychology was a constant throughout history was believed by some of the greatest historians of the eighteenth and nineteenth centuries. J. Burckhardt took as the starting point of his *Considerations on Universal History* man "as he is, as he has always been and as he should be."[10] Therefore, we substituted modern Western European men for men of other periods and cultures. There is no universal yardstick, applicable to all civilizations and all eras because there are no two identical men in any period.

Sciences differ from one another in their methods, their fundamental statements, their procedures of investigation and verification, their theoretical models, and their development. To persevere us in this belief would mean, as L. Giard aptly suggests that we would be erecting a specific science at a given moment of its history as a model of scientific excellence, then demand that all other types of knowledge, in order to become a science should present equivalent elements, taking into account the variations between the objects of study.[11]

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9 A demonstration is a form of reasoning that establishes the necessity of a truth. It proceeds by logical sequences that follow rigorous rules. A demonstration brings to a form of knowledge its universal value. It allows one to affirm that a form of knowledge is true in all cases since one can reiterate the demonstration to prove the accuracy of this knowledge. On demonstration in ancient sciences, see for example the scholarly contributions in the special issue of the journal *Pallas* (nº 69, 2005).

10 Gourevitch, *Les catégories de la culture médiévale*, p. 7.

11 Giard, "L'ambiguïte du mot 'science' et sa source latine," p. 46.

### 1.2.2 The Issue of Progress in Byzantine Science

Besides the above-mentioned criticism of their working methods, Byzantine scholars also suffer from another deprecating judgment from some modern scientists.[12] One often reads that Byzantine science, throughout the eleven centuries of the Empire's existence, made no substantial progress. This negative assessment is used as a pretext to sweep away most Byzantine scientific contributions. But this attitude is somewhat naïve. From the point of view of the accumulation of knowledge alone, Byzantium provides evidence of continuous progress! And, if one understands progress in terms of qualitative leaps, there have also been, in some scientific fields at least, notable advances and this is confirmed by some of the chapters in this volume, highlighting cutting-edge and often unpublished research.

Generally speaking, no matter how the idea of progress is conceived, it was irrelevant to medieval culture. While science since the seventeenth century shares a privileged relationship with the idea of a progress, this was not the case in the Byzantine period. In other words, the Byzantines did not see scientific production as an evolutionary process building on the scientific knowledge of their predecessors. If a history of Byzantine science must account for transformations and changes, the reader should not expect to be presented with a progress-to-date report. As G. Canguilhem wrote, the history of science is not an inverted account of scientific progress, a visualisation of outdated stages, with today's truth as its vanishing point. It should be an effort to find and understand how outdated notions or attitudes or methods were, in their own time, a progress and therefore how an outdated past should retain a scientific label. Understanding the directives of a period is as important as explaining their destruction in later periods.[13]

## 1.3 *The Byzantine Epistemological Context*

### 1.3.1 Issues of Terminology

One should add to these two critical attitudes towards Byzantine scholars and their scientific output the contemporary debate around the term "science" found in many publications. Is one justified in using this term to refer to knowledge that predates the historical conception of what is considered science today?

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12 On the negative attitude of several modern scholars towards Byzantine scholars and their scientific works, we refer the reader to the historiographical section in chapters 3 to 13 of this volume.

13 Canguilhem, "L'objet de l'histoire des sciences," p. 14.

For some researchers, this term should be restricted to what corresponds closely to the sciences in their current form. Another option is to extend, by analogy, the use of the term "science" to periods that predate the first so-called "scientific revolution" (the seventeenth century), although the idea itself of a "scientific revolution" linked to a specific historical period is increasingly called into question. To avoid confusion, some researchers propose to use terms like "knowledge" or "proto-science" instead of "science."[14] But these other words, tend to stigmatize former scientific production and create more confusion than clarification. In truth, to try to define criteria to distinguish "prescientific" knowledge from "scientific" knowledge is a methodological aberration.

Even though the word is of Latin origin, "science" is a modern not an ancient category. It derived from the verb *scire* "to know," and its adjectival present participle form, *sciens*, "who knows, is educated, has knowledge of." The substantive *scientia*, "knowledge, science [in the broad sense]" is abundantly attested in classical Latin. In the words of J. Weisheipl, "in early Latin usage the verb simply meant to discern, or to penetrate to the bottom in the sense of cutting a situation to its very roots. Thus in Latin the term *Scientia* was used to designate a discerning, penetrating, intellectual grasp of a situation or of a given subject."[15] The word *scientia* then passed into Christian and medieval Latin. Thus, Boethius, in his translation of Aristotle's Categories (*In Categorias*) translated the Greek *episteme* by *scientia*. Around 1260 William of Moerbeke made the same choice as Boethius for the couple *episteme-scientia* in his own translation of the Categories.

In Greek, the term *episteme* refers to knowledge that is true and certain, related to the verb *epistasthai*, knowledge, whose etymological meaning (*epi* [*over*] + *histasthai* [*to stand*]) is "to be placed above," that is to say, "dominate" the subject of study.[16] If Plato was aporetic in the *Theaetetus*,[17] Aristotle, however, thought that *episteme* referred to general theoretical knowledge (*Nicomachean Ethics*, 1094a, 1140a).[18] He distinguished experience (*empeiria*) or

14 See also Lloyd, *Early Greek science: Thales to Aristotle*; Brunschwig/Lloyd/Pellegrin (eds.), *Le savoir grec*.

15 Weisheipl, "Classification of the Sciences in Medieval Thought," p. 54.

16 See also Chantraine, *Dictionnaire étymologique de la langue grecque*, s.v. ἐπίσταμαι; Snell, *Die Ausdrücke für den Begriff des Wissens in der vorplatonischen Philosophie*, p. 81 sqq.

17 See also Cornford, *Plato's Theory of Knowledge: The Theaetetus and The Sophist*; Dillon, "Theories of knowledge in the old Academy." To summarise, one could say that "in this dialogue, Socrates and Theaetetus discuss three definitions of knowledge: knowledge as nothing but perception, knowledge as true judgment, and, finally, knowledge as a true judgment with an account. Each of these definitions is shown to be unsatisfactory."

18 On Aristotle's use of the term, see Hanley, *Being and God in Aristotle and Heidegger: The Role of Method in Thinking the Infinite*, p. 4 sqq.

knowledge of individual things, art (*techne*) or the practical knowledge of universal things and *certain* knowledge (*episteme*) or the intellectual knowledge of first causes and principles of beings. This idea of a philosophical knowledge deriving from the causes suggests that *episteme* included the *mathemata* in the Pythagorean sense,[19] as well as the rational knowledge obtained by reasoning "according to the logos," i.e., according to reason.[20]

Besides *episteme* (knowledge) in ancient Greek, one also finds the terms *philosophia* (love of wisdom, philosophy), *theoria* (contemplation, speculation) and *peri physeos historia* (a survey of nature). They are all employed in specific contexts where their translation by the word "science" is (or at least should be) obvious and hardly risks misleading the reader. But if these terms are used to designate certain intellectual disciplines we think of as scientific, each time the term is used it may mean something quite different from our term "science." By using the term "science" the authors of this book, starting with myself, are aware of this issue. They use it as a shorthand to refer to certain Byzantine ideas and theories of Byzantine authors.[21]

### 1.3.2 The Byzantine Epistemological Postulate

Even if Byzantine society did not develop science as it is understood in modern and contemporary times, after this brief overview we can, I think, use the word science and identify the (literary, visual, technological) production of certain Byzantine scholars as scientific while remembering that, with regard to our

19 *Mathema* referred originally to an empirical, practical or theorical form of knowledge. For the pythagoricians, according to their later commentators, it had taken a more precise meaning, that of demonstrated knowledge. This explains Iamblichus' title *Peri tes koines mathematikes epistemes*. Such a conception explains why the *mathemata* were then designated both as mathematical fields (arithmetic, plane and spatial geometry) and physics (optics, harmony, astronomy, mathematics). Four of these disciplines (arithmetic, geometry, astronomy, musical acoustics) formed the *Quadrivium* of the neo-platonicians (on the *Quadrivium*, see also below, n. 66 and 68).

20 See also O'Meara, "Conceptions of Science in Byzantium."

21 Indeed, when they do use the word "science," they accept the terminological anachronism by classifying the claims of Byzantine knowledge according to modern scientific disciplines, such as mathematics, astronomy, geography, optics, botany, and so forth. Alternatively, when they refer to that large body of natural knowledge that included cosmology, physics, matter theory, and psychology, scholars speak of "natural philosophy," which is the Aristotelian term that the Byzantines also used and which designated a philosophical discipline that was clearly linked to metaphysics and theology already by Aristotle himself—and even more clearly so in Greek and Latin Christianity (see for example chapter 5 of this volume). Some other researchers specify "hard sciences" and "natural sciences," a distinction which seems anachronistic and likely to mislead the reader (e.g. Reymond, *Histoire des sciences exactes et naturelles dans l'antiquité gréco-romaine*).

current usage, the term is ambiguous. Byzantine scholars for the most part tried to explain and understand nature through the almost exclusive prism of the new religion, a worldview which may seem today to be strange and irrational. In a famous historical anecdote, Napoleon I flipping through the pages of Pierre-Simon Laplace's *Celestial Mechanics*, wondered why there was no mention of God anywhere in his treatise. Laplace answered: "God? Sire, I did not need that hypothesis." In his view, God was a hypothesis that explained everything but did not predict anything, which is why it was not used in the context of scientific research. And indeed, modern science does not require an initial motor, or a higher reason, a god, a creator, regardless of the name that we want to give this numinous force.

However, we risk completely misunderstanding the culture of the Middle Ages if we were to think that ignorance and obscurantism prevailed because their system of thought was theocentric. The Byzantines were unable to explain the world and orient themselves without this "hypothesis" which was not for them a hypothesis, but a postulate, an absolute necessity for their worldview and their conscience. What may seem wrong for us today was not for men of that time, for whom God was a supreme truth which extended into all their representations and ideas, a truth to which all their cultural and social values referred.

Scientific curiosity among Byzantine scholars was often not expressed in the same way as it is today. This does not mean that the fruit of their intellectual effort was less scientific. Until recently, it was still claimed that if there was no third dimension in Byzantine art, it was because the Byzantines did not know how to do it. This was not, however, the result of ignorance since their ancestors were already significantly advanced in this field. In fact, in Byzantine art, space was considered to lie beyond the province of rational inquiry. The old Hellenistic systems of representation were abandoned. And the rejection of the third dimension was a conscious refusal, because the worldview had changed and consequently the role of art had changed with it. A similar observation must be applied to the way the Byzantines practiced science.

### 1.3.3 The Origin of Byzantine Knowledge

Now let us return to the issue of the Byzantine contribution. Does it limit itself, as it is often claimed, to keeping and transmitting ancestral knowledge? From the outset we should remind ourselves that not all Byzantines respected the writings of their Hellenic forebears. In fact, several Byzantine scholars rejected ancient scientific writings suspecting them of paganism.

This declared hostility to the knowledge found in pagan books is found in many authors, like John Philoponus in the sixth century,[22] Ioannis Psichaïtae in the ninth century[23] or Basil Camateros in the twelfth century.[24] Even if sometimes their opinions were not as clear-cut as portrayed in modern studies, the few Byzantines mentioned here are known to have explicitly shown their hostility to ancient scientific writing.[25] As pagans they considered it unnecessary to know God or save one's soul.[26] Conversely, many scholars were interested in Hellenic science.[27] They studied it and not only did they try to preserve it but they also tried to contribute to it and develop it out of their

22 He writes in his *De opificio mundi*: "Who would be able to state the cause of these things? No more could any human being give an account of the number of the stars, their position and other, and the difference in their magnitudes and colours. This only we can say, that God has made everything well and as is needed, neither more nor less. Altogether we know the causes of few things. If therefore people cannot give the natural cause of things that are apparent, they should not keep asking for the cause of things that are not apparent.," τίς ἂν οὖν τὴν αἰτίαν τούτων εἰπεῖν ἔχοι; οὐδὲ γὰρ τοῦ πλήθους τῶν ἀστέρων, θέσεώς τε αὐτῶν καὶ τάξεως μεγέθους τε καὶ χρωμάτων διαφορᾶς λόγον ἀνθρώπων οὐδεὶς ἀποδώσει ποτέ· μόνον δέ, ὅτι πάντα καλῶς καὶ ὡς ἔδει πεποίηκεν ὁ θεὸς καὶ οὐδὲν ἐλλεῖπον ἢ περιττόν, πιστεύομεν ἅπαντες· ὀλίγων γὰρ κομιδῇ τὰς αἰτίας ἐγνώκαμεν. εἰ οὖν αἰτίαν τῶν φαινομένων εἰπεῖν οὐκ ἔχουσι φυσικήν, μηδὲ ἡμᾶς τῶν μὴ φαινομένων ἐπερωτάτωσαν αἰτίαν, *De opificio mundi*, III, 4, ed. Reichardt. See also Sorabji (ed.), *Philoponus and the Rejection of Aristotelian Science*.

23 See *Vita Joannis Psichaïtae* (BHG 896), ed. Van den Ven, pp. 17–18.

24 See *Laudatio patriarchae Basilii Camateri*, ed. Loukaki, pp. 52–54.

25 This is the case for example of John Philoponus. In *Against Aristotle* he addressed Aristotle's belief on the aether and the eternity of movement. His criticism crystallised in eighteen books he published in 529 *De aeternitate mundi*, against the Neoplatonic theories of the Athenian scholarch Proclus. He also wrote a treatise on the astrolabe and a commentary on Nicomachus of Gerasa's *Introduction to arithmetic*.

26 And in the following centuries, the debate would only intensify between intellectuals around the use or rejection of the Greek philosophical and scientific heritage. Three major thinkers appropriated the philosophical culture of Byzantium: Nikephoros Gregoras (Metochites' disciple), Gregory Palamas, the leader of an important monastic movement and Barlaam, a monk who came from Calabria, well educated in Latin philosophy and theology.

27 The Christianization of pagan culture has often been studied. On this topic, see for example the recent work by Inglebert/Destephen/Dumézil, "Le problème de la christianisation du monde antique"; Perrot, "Les chrétiens et l'hellénisme : identités religieuses et culture grecque dans l'Antiquité tardive"; Larsen/Rubenson, "Monastic education in late antiquity: the transformation of classical paideia." However, few researchers have focussed on the way in which early Christians re-appropriated scientific literature (see Inglebert, Interpretatio christiana: *les mutations des savoirs* (*cosmographie, géographie, ethnographie, histoire*) *dans l'Antiquité chrétienne 30–630 après J.-C.*; Theodosiou/Manimanis/Dimitrijevic, "The Contributions of the Church in Byzantium to the Natural Sciences Byzantine Astronomers and Scientists"; Nicolaidis, *Science and Eastern Orthodoxy: from the Greek fathers to the age of globalization*; Lazaris, *Le* Physiologus *grec*, pp. 101–18; Nicolaidis/Delli/Livanos et al., "Science and Orthodox Christianity: An Overview").

worldview and with the means at their disposal.[28] Some did not hesitate, moreover, to challenge the ideas of their ancestors, even some of the most illustrious thinkers like Aristotle or Ptolemy and turned to works from other cultures, Western, Arab or Persian.

Byzantine science was a product of two sources. On the one hand were the numerous scientific treatises from antiquity. These never ceased to be copied through all the centuries of Byzantine history, often accompanied by commentaries emanating from the schools of Alexandria, Athens, or Syria at the end of antiquity. This was a constant source of nourishment for Byzantium's scientifically-minded scholars. On the other hand, there was foreign material, mainly of Islamic origin but also Latin and Hebrew, which often inspired their work.

## 2 A New Perspective on Byzantine Science

### 2.1 *Openness to External Knowledge and Byzantine Innovations*

It would be inappropriate to list in this introduction the scientific exchanges with and influences of works by other cultures on Byzantine production.[29] Let us note, however, that scientific contacts between the Byzantines and scholars of neighbouring cultures were in place earlier than was recently thought. On this topic, M. Mavroudi wrote: "A number of Greek texts on empirical science that were written before the year 1000 are either avowed translations from Arabic originals or indirectly indicate earlier Byzantine contact with Arabic science."[30]

If we focus on astronomy for example, it is now certain that, at least from the eleventh century, and based on the evidence of some translations of Arabic star catalogues, Islamic astronomy began to be familiar to the Byzantines. This included the writings of Symeon Seth (and possibly the scholium of 1032 to the *Prolegomena to the Almagest*), and an anonymous astronomical treatise written between 1072 and 1088.[31] Even Isaac Argyros, who is generally represented

28 The tension between these two trends—the continuity between science and Christian belief and the contradiction between science and Christian belief—permeates the intellectual history of Byzantium and we will observe a range of positions between two extremes.

29 On the topic, see Kaldellis, *Catalogue of Translations into Byzantine Greek* (version III), pp. 26–40.

30 Mavroudi, *A Byzantine book on dream interpretation the 'Oneirocriticon' of Achmet and its Arabic sources*, p. 395. See also Magdalino, "The Road to Baghdad in the thought-world of ninth-century Byzantium."

31 See most recently, Tihon, "Premier humanisme byzantin : le témoignage des manuscrits astronomiques"; Bardi, "The Reception and Rejection of 'Foreign' Astronomical Knowledge in Byzantium."

as a fervent defender of Ptolemy's astronomy, demonstrates a definite interest in Persian astronomy.[32] Around 1347, George Chrysococces wrote a treatise entitled *Persian Syntaxis* based on the *Zīj-i Īlkhānī* of Naṣīr al-Dīn aṭ-Ṭūsī. The *Persian Syntaxis* was widely diffused, and its circulation was established in the second half of the fourteenth century and the fifteenth century. Chrysococces' writing follows the work of Gregory Chioniades, who lived approximately between 1240 and 1320. In the early 1290s he travelled to the court of the Īl-Khāns at Tabrīz, where he studied astronomy under Shams al-Dīn al-Bukhārī. Between November 1295 and November 1296 Shams dictated to him (in Persian) the rules for using the ʿAlāʾī Tables of al-Fahhad, which Chioniades rendered into barbaric Greek as the *Persian Astronomical Composition*. Chioniades was back in Trebizond by September 1301 and later in Constantinople. He trained students in Constantinople in Persian astronomy and medicine. Furthermore, three Jewish astronomical works were the object of Byzantine adaptation: the *Six Wings* (*Shesh Kenaphayim*) of Emmanuel Bonfils of Tarascon (*c.* 1365); the *Cycles* of Bonjorn (Jacob ben David Yom-Tob, Perpignan, *c.* 1361); and the *Plane Way* (*Orah Selulah*) of Isaac ben Salomon ben Zaddiq Alhadib. Western astronomy was introduced into the Byzantine milieux of Cyprus around 1340 (in a treatise on the astrolabe, Toledan Tables), and in 1380 Demetrius Chrysoloras composed a Greek adaptation of the Alfonsine Tables. In 1252, during the Latin occupation of Constantinople, a treatise (*Great Computation according to the Indians*) was written on the use of Indian numerals. It is not clear whether it was based directly on an Arabic source (it transliterates some Arabic technical terms and uses the epoch of the Hijra in an example) or a Latin version like the Book of the Abacus of Leonardo of Pisa (who is known to have visited Constantinople).[33]

Astronomy, but also medicine, including hippiatrics, was one of the scientific fields in which some Byzantine scholars were cautiously following the achievements of the Greeks and Romans. Indeed, it should be noted that since H.-J. Sévilla's seminal work, we now know that Byzantine veterinarians understood and exploited the writings of their immediate predecessors and they also inherited knowledge from the Egyptian and Babylonian civilisations.[34] Although this was not the case for all Byzantine veterinarians, some at least

32 He reproduced in the Florence, Biblioteca Medicea Laurenziana, Plut. 28.13 a treatise entitled Παράδοσις εἰς τοὺς περσικοὺς κανόνας τῆς ἀστρονομίας (on this treatise and its relationship with Argyros, see Mondrain, "La lecture et la copie de textes scientifiques à Byzance pendant l'époque paléologue," p. 630).

33 See for example Allard, "Le premier traité byzantin de calcul indien: classement des manuscrits et édition critique du texte."

34 See Sévilla, "L'hippiatrie byzantine du IVᵉ siècle. Ses sources orientales."

did not hesitate to turn to treaties from other cultures. Similarly, within human medicine, we know that Byzantine doctors did not simply parrot and transmit verbatim ancient written sources, but used them carefully, rearranging, truncating, and supplementing them out of contemporary experience. Close examination of Aetios of Amida's use of Galen's notions of drug theory, for example, shows how Aetios chose precisely those passages that would explain the Galenic idea of "drugs by degrees," a classification system of pharmaceuticals that would be the standard in medicine until the eighteenth century. Certainly as a tributary of Greco-Roman ideas, Byzantine medicine was enriched over the centuries by other traditions and developed as a scientific domain, alive and innovative. While they were recovering, reorganizing, and diffusing the Greek legacy, Byzantine scholars were also assimilating Arabic medicine, including medical botany. As A. Touwaide pointed out, Arabic and Greek plant specialists might have been working together in Constantinople, giving the Byzantines access to Arabic plant science (see chapter 10 of this volume). Among others, Symeon Seth shows traces of Arabic experiments. Al-Razi's brief treatise *De Pestilentia* was translated from the Greek (περὶ λοιμικῆς). Indeed, as noted by B. Mondrain, "from the thirteenth century, translations from the Arabic, Persian or Latin are widely disseminated."[35] Thus, in addition to the al-Razi's text, one might mention Ibn al-Ǧazzār's *Ephodia* (Ἐφόδια τοῦ ἀποδημοῦντος)[36] the translation of which is attributed to Constantine of Reggio, a physician from Southern Italy in the eleventh century.[37]

Nicholas Myrepsos is probably the author of a late Byzantine compilation of pharmaceutical recipes, collected in a work called the *Dynameron* and attributed to "Nicholas." Nicholas Myrepsos (Μυρεψός, lit. "preparer of unguents") is traditionally identified with the Nicholas who was chief physician at the court of John III Vatatzes in 1241. According to the reconstructed history of this treatise, it was probably written in the second half of the thirteenth century, after a shorter book of recipes (*Antidotarium parvum*) by Nicholas of Salerno (twelfth century), that is to say, after a Latin text. In turn, the Greek treatise was translated into Latin from the first half of the fourteenth century by Nicholas

35 Mondrain, "La lecture et la copie de textes scientifiques à Byzance pendant l'époque paléologue," p. 625.

36 On the Zād al mussāfir wa tuhfatu elqādim and its Greek translation, see Miguet, "Premiers jalons pour une étude complète de l'histoire du texte grec du 'Viatique du Voyageur' (Ἐφόδια τοῦ ἀποδημοῦντος) d'Ibn al-Ǧazzār."

37 Another translation of this treatise is due to a certain Constantios of Memphis, who explains that he has added many recipes from Arab and Greek doctors. The original text was therefore transformed to such an extent that, as highlighted by M.-H. Congourdeau, it cannot claim to be a translation *stricto sensu* (Congourdeau, "La médecine byzantine à la croisée de l'Orient et de l'Occident," p. 227).

of Reggio.[38] One can also discern foreign influences, even in the teaching of scientific subjects. John Argyropoulos for example, educated in Italy (Padua), was marked by a Western influence in the way he taught medicine at the hospital attached to St. John Prodromus monastery in the neighbourhood of Petra in Constantinople.[39]

Moreover, practical needs stimulated the writing of veterinary manuals, tracts on parasitology, and treatises on pharmacy. By medieval standards the practice of medicine existed at a high level of expertise: hospitals were to be found not only in Constantinople, but also in the provinces. Byzantine medicine had professional specializations, including obstetrics and gynaecology, ophthalmology, dermatology, and dentistry. Thanks to Byzantine pharmacy, many diseases received sophisticated treatments, and the medical tracts of Alexander of Tralles and Paul of Aegina show the variety of drugs prescribed for ailments of the chest, heart, digestive system, and other organs. Byzantine surgery was also highly advanced; listings of surgical instruments suggest specialized expertise, perhaps derived from the known instances of dissections and autopsies performed by Byzantine physicians and surgeons.[40] The *Vita Theophanis Confessoris* by Nikephoros Skeuophylax written in the tenth century, mentions a fascinating surgical operation undergone by Saint Theophanes for his kidney stones (ed. de Boor, p. 23). The physicians passed instruments up Theophanes' urinary tract, ground down the stones inside the bladder, and then allowed the fragments to pass out of the body with his own urine. Other ancient sources only mention surgeries which involved cutting

38 See Weiss, *Medieval and Humanist Greek*, pp. 124–35; Cavallo, "La trasmissione scritta della cultura greca antica in Calabria e in Sicilia tra i secoli x–xv," pp. 233–35.

39 See also Mondrain, "La lecture et la copie de textes scientifiques à Byzance pendant l'époque paléologue," pp. 618–19.

40 Indeed, in 1903, H. Schoene published the names of 54 'Greek-Roman' surgical instruments. For the first time, J. S. Milne (1907) attempted to attribute names to the Byzantine instruments and found their Byzantine names; and, since then, with the additions of A. Maraslis (1983) and L. J. Bliquez (1985) the list has increased to 237. Several instruments, however, have different forms, shapes and names, and some were obviously made for particular operations, thus increasing the number of the various known Byzantine instruments to over 500. See most recently—including previous bibliography—Geroulanos/Panaretos/Lyberopoulou, "Surgery in Byzantium." Let us add as well surgical instruments which the Byzantines, judging from the small datable number of instruments that were discovered, closely followed Hippocrates' recommendations: "Instruments must all be easy to use, as to their weight and fine construction." Unlike Arab and Western surgical instruments which were often decorated, sometimes in excess (and this was the case until the eighteenth century), which prevented them from being thoroughly cleaned, this was not the case in Byzantium and would only become the standard after 1867, with Joseph Lister, and the development of antisepsis.

into the bladder to remove the stones. This bloodless operation was a truly innovative type of surgery and well in advance of ancient practice. Even the well-versed seventh-century scholar Paul of Aegina only knew kidney-stone operations involving incisions. Thus, Byzantine "obscurantist" physicians were capable of major innovations.[41]

We should add to this the surgical operation that focussed on the separation of Siamese twins described in several Byzantine texts.[42] Finally, let us emphasize that for the authors of a study on the "facial reconstructive procedures" performed by physicians during the Byzantine period, the principles of reconstruction "followed the same patterns of mobilisation and preparation of local flaps as those used today."[43]

As A. Mylonas, E.-F. Poulakou-Rebelakou and G. Androutsos, have noted, Byzantine physicians developed a number of interesting concepts, views and opinions referring to the field now recognized as Oral and Cranio-maxillofacial Surgery and Pathology. And they explain that

> the most eminent physicians of the Early (fourth–seventh centuries AD) and Middle (eighth–twelfth centuries AD) Byzantine Period, in particular Oribasius Pergamenus, Aëtius Amidenus, Alexander Trallianus, Theophilus Protospatharius, Paulus Aegineta, Meletius Monachos, and Leo Medicus, in their works deal with topographic and surgical anatomy of the head and neck, and a large list of related topics, including dentoalveolar surgery, oral and cervicofacial infections, trauma of viscerocranium and neurocranium as well as the biomechanics of traumatic brain injuries, temporomandibular joints dysfunction as a consequence of mandibular dislocation, surgical oncology and reconstructive surgery of the head and neck, oral pathology, surgical pathology of salivary glands, therapeutic management of facial nerve dysfunction, preprosthetic surgery, craniofacial surgery, and deformities of the facial skeleton involving anthropologic and craniometric observations. Clinical examination of patients presenting corresponding functional and aesthetic problems is considered, using recognizable orthodontic and orthognathic surgical approaches. Finally, specific bandages of the head and neck are described,

41 The revelations of L. Bliquez and A. Kazhdan, thus, prove that Byzantine physicians were conducting autopsies until the twelfth century at least (Bliquez/Kazhdan, "Four testimonia to human dissection in Byzantine times").

42 See Pentogalos/Lascaratos, "A Surgical Operation Performed on Siamese Twins During the Tenth Century in Byzantium."

43 See Papadakis/Sfakiotakis/Fragakis et al., "Plastic Surgery of the Face in Byzantine Times," p. 155.

> for treating traumatic injuries of the viscerocranium and neurocranium, diastasis of the cranial sutures, dislocations of the mandible (unilateral and bilateral), as well as inflammatory diseases of the parotids and the neck."[44]

Finally, and even if this volume does not cover technology directly (irrigation and water supply, bridges, roads, building construction, gears, water-raising machines, and *Automata*[45]),[46] we should mention, that several chapters touch on the Byzantines' prowess and inventiveness in this area.

The fifth to the ninth centuries, for example, brought forth significant technical innovations, especially in fields like agriculture, transport, and especially military equipment and weaponry. Thus, we now know that the Byzantines knew (and probably had developed) a riding stirrup before the appearance of the Avar stirrup in about 590–600 CE. The invention of this tool, which was extremely important in ensuring increased stability for mounted archers and ensuring also shooting accuracy, opened up radical changes in the structure of the Byzantine army.[47] Similarly, recent research has shown that, at least since the sixth century CE, the Byzantines used a special type of horseshoe during military campaigns.[48] The lateen sail, in use probably from the seventh century, made ships more responsive to the wind. Greek fire was invented in the seventh century, and finally, the water mill became a standard power source by the time of the Farmer's Law.

## 2.2 *Another Approach to Byzantine Science*

### 2.2.1 The Diversity of Ancient Sources

These examples show that when some Byzantine scholars needed to consult other texts than those of their ancestors, they did not hesitate to do so. Based

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44 Mylonas/Poulakou-Rebelakou/Androutsos, et al., "Oral and cranio-maxillofacial surgery in Byzantium," p. 159.

45 Devices (mechanical singing birds, roaring golden lions…) powered by compressed air from bellows or by water (see also chapter 3 of this volume).

46 See, for example (in chronological order): Feldhaus, *Die Technik der Antike und des Mittelalters*; Raper/Singer, *A history of technology*; Field/Wright, *Early Gearing—Geared mechanismsin the Ancient and Medieval World*; Hill, *A history of engineering in classical and medieval times*; Lazos, *Μηχανική και τεχνολογία στο Βυζάντιο. Αστρονομία και όργανα μέτρησης του χρόνου*; Valavanis/Vachtsevanos/Antsaklis, "Technology and Autonomous Mechanisms in the Mediterranean: From Ancient Greece to Byzantium."

47 See Lazaris, "Considérations sur l'apparition de l'étrier : contribution à l'histoire du cheval dans l'Antiquité tardive."

48 See Lazaris, "Considérations sur l'apparition du fer à clous : contribution à l'histoire du cheval dans l'Antiquité tardive."

upon their own experience they did not hesitate to improve their instruments and their surgical techniques. Therefore, in contrast to the decades-old image of a profoundly ossified group of Byzantine scholars locked within their world view and blindly fixated solely on the writings of their ancestors, we have discovered many Byzantine scholars (from a list of 240 savants that has emerged from a first survey of a work in progress) whose work has called in question these negative assumptions.

As we move forward and increase our knowledge of as yet unpublished Byzantine scientific texts we should expect further surprises. Indeed, in the field of Byzantine science, so many texts remain unedited or simply ignored that one cannot claim to be giving an all-encompassing account of Byzantine scientific achievement.

Moreover, we must not forget that, in addition to the classical Greek texts copied and preserved by the Byzantines,[49] scholars of the Western Middle Ages and, later, Renaissance humanists also had access to Byzantine commentaries on these texts. In other words, their comments, which are a neglected aspect of the Byzantine scientific contribution, have nevertheless helped expand scientific knowledge from the Renaissance onwards.

Finally, let us add to this list the Byzantine contribution to the development of science through visual documents designed and realized for many classical texts that did not originally contain images. Without wishing to expand on the subject, I will simply mention here Neophytos Prodromenos and his editorial activity in the Monastery of St. John Prodromos in Constantinople. Originally from Western Macedonia, he experienced a period of intense production between 1350 and 1365. He was the author of an epitome on logic, a Constantinopolitan version of the *Corpus aristotelicum*, as well as a Botanical lexicon. He also produced several manuscripts with medical content, and his work is punctuated by diagrams and figurative representations. As A. Durr explains, “this use of graphic forms is not trivial and testifies, if not a recourse to the image, at least a positive attitude towards it.”[50] Many images in Byzantine scientific manuscripts are therefore original creations that often go beyond mere visual commentary. They contributed to the transmission of Byzantine scientific thought to the medieval West, before helping to shape the ideas of humanists on the scientific image and its place in intellectual work.[51]

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49 I do not deal here, even if their contribution is indisputable, with Syriac and Arabic translations of several Greek scientific treatises and their transmission to the West.

50 Durr, *L’image toxicologique à Byzance*, p. 417.

51 On scientific illustration in Greek manuscripts, see Lazaris, “Scientific, Medical and Technical Manuscripts”; Lazaris “Donner à voir les savoirs scientifiques dans les mondes byzantin et latin (IVe-XIIe siècles).”

### 2.2.2 The Historical Context of Byzantine Science

The actual contribution of the Byzantines is therefore more important than has been claimed, at least in certain scientific fields. It is true, however, that during the Empire's eleven centuries, and as was mentioned at the beginning of this introduction there was a certain decline in scientific production compared with previous historical periods. To understand this phenomenon, however, we must take into account many, technical, economic, social, political, ideological and/or religious parameters.

Byzantine science encountered many difficulties: the arrival of a new religion and the hostility of some fervent Christians to pagan scientific texts, the plague of the sixth century, the Arab invasions[52] and iconoclasm.[53] One can also add the lack of interest, with few exceptions, on the part of the Byzantine imperial power in scientific achievement. Except when hospitals were doubled with medical schools the Byzantine rulers in contrast to Alexandria or the Arab-Muslim world,[54] never created foundations devoted exclusively to science. The few exceptions of imperial support were successful, but only occasionally because they were neither durable nor solid. A rare departure from the rule that is germane to the fields under discussion in this volume, was the so-called first Byzantine humanism.[55] The lack of an educational programme, stable over time and adapted to peoples' needs, hindered the regular and positive

52 In addition to the loss of schools like Antioch because of these invasions, several other schools were decimated by epidemics or destroyed by natural disasters. It is quite probable that the plague epidemic of 551 caused the law school of Constantinople to cease to operate. The earthquake that occurred the same year destroyed the famous law school of Berytus (Beirut). While these schools are not directly related to the teaching of scientific subjects, their loss impacted on the dissemination of science as well.

53 The future seemed uncertain in the period between the seventh and ninth centuries, which favoured astrology that allegedly could predict the political future of the empire. Thanks to the survival of astrology, other disciplines, like mathematical astronomy (which was absolutely necessary to alchemists) were preserved or in some cases even developed. On education and science during the iconoclast period, see Moffatt, "Schooling in the Iconoclast Centuries"; Tihon, "L'astronomie à Byzance à l'époque iconoclaste (VIIIe–IXe siècles)."

54 For an overview of the issue, see De Smet, "Sciences étrangères et sciences islamiques."

55 See Lemerle, *Le premier humanisme byzantin : notes et remarques sur enseignement et culture à Byzance des origines au Xe siècle*; Flusin/Cheynet (eds.), *Autour du Premier humanisme byzantin & des Cinq études sur le XIe siècle, quarante ans après Paul Lemerle*, notamment Magdalino, "Humanisme et mécénat impérial aux IXe–Xe siècles." The work of Irigoin, "Survie et renouveau de la littérature antique à Constantinople (IXe siècle)" is still useful. To understand the birth of this cultural and scientific renewal, the reader will find a different point of view than P. Lemerle's in Gutas, *Greek thought, Arabic culture: the Graeco-Arabic translation movement in Baghdad and early ʿAbbāsid society, 2nd–4th/8th–10th centuries*, pp. 175–85.

development of new ideas.[56] In addition, as E. Nicolaidis notes, "the centralized system of Byzantium, together with the importance of the town of Constantinople compared to the other towns of the empire, prevented the development of the high schools newly created in other cities. The school of Thessalonica, the second most important city of the empire, was an exception, but it soon declined. During the same period [end of 12th C.], in the Latin West the newborn universities multiplied. These universities, unlike Constantinople's high schools, had a certain autonomy, at least in the appointment of professors. In centralized Byzantium, the emperor and the patriarch nominated their protégés as heads of the university and the Patriarchal School. Thus, the status and the protection provided to science by the heads of the empire carried the seeds of stagnation. Although scientific teaching progressed, there were no vigorous discussions of scientific matters."[57] Byzantine scholars were consequently often deprived of all state aid and this was reflected in their education; many scholars were actually self-taught, men trained in the family circle, using the books of the family library, or from a master while participating in *synanagnoseis* ('common readings') in a reading circle (see below, pp. 23–24 and also chapter 2 of this volume).

Let us add that the empire has always experienced great instability and several emperors have spent the largest part of their reign in endless struggles with internal or external enemies. The insecurity and the anxiety did not favour the emergence and especially the consolidation of new ideas. There is one notable exception, however, during the rule of the Palaiologan dynasty, particularly between 1270 and 1330 (extending to 1361 and Nicephorus Gregoras' death).[58] By then, however, Byzantium was already struggling for its

56 A map published by D. Goodman and C. Russel (it came originally from the 101st edition [Berlin 1990] of the *Historischer Weltatlas* by Fr. W. Putzger), shows the range of European universities between the late twelfth century and the 1500s, from Lisbon in the west to Uppsala in the North and Cracow in the East. Thus, while the medieval university system spread to the very limits of inhabited Europe in the west, north, and south, it did not in the east. See Goodman/Russell, *The Rise of Scientific Europe 1500–1800*, map 1.4, p. 25. On this phenomenon, see also Lüthy, "Theology and Science in the Orthodox World: Some Doubts from a Latin Perspective."

57 Nicolaidis, *Science and Eastern Orthodoxy: from the Greek fathers to the age of globalization*, p. 68.

58 The recovery of Constantinople by Michael VIII Palaiologos in 1261 was followed by a swift and massive movement of intellectuals heading to restore the capital as a centre of learning and research. Despite political troubles and military crises, the reigns of Michael VIII and Andronicus II were a golden age for scholarship (and classical scholarship in particular). However, one must note three events that are rarely found combined in the previous periods and their important role in this cultural and humanistic renewal. Indeed, as opposed to the relative diffidence of monks towards Classical wisdom in

survival and was living the last centuries of its existence. By the 1340s, the spiritual development of *hesychasm*, which preached the supremacy of the religious authorities over the secular ones combined with the Black Death (1348–1453)[59] to worsen an already weakened situation. None of this encouraged significant intellectual leaps of the kind that took place among, for example, the Italian humanists.

If one wants to have a clearer understanding as to why the production of new scientific ideas in the Middle Ages slowed down, particularly in Byzantium, another factor must be taken into account. This is linked to difficulties related to the accumulation of textual data, which was intertwined, inter alia, with the passage from the roll to the codex and, later, from the upper case to the lower case. In order to exploit the mass of information that was constantly increasing with successive copies and new texts, for a very long time the Byzantines sought to generate different auxiliary reading techniques. In addition, instruments (summary, tables, indexes and alphabetical tables of subjects) were gradually developed and these provided a great deal of flexibility in searching within a specific text or even within a particular manuscript, and were able to quickly identify any passage for which one might be searching.[60] Thanks to all these inventions, the book as an instrument of intellectual work was born, but these changes required several centuries of reflection and testing before becoming the norm.

In order to arrive at a better understanding of dwindling Byzantine scientific production these parameters should be taken into consideration.

previous times, a crucial role was played in this age by the monasteries of the capital, such as the Akataleptos, the Christ Soter, the Pantokrator, and above all the monastery of Chora. Additionally, two decisive moves were the restoration of the patriarchal school by Germanus III (1265–1266), and the creation of an imperial school by Michael VIII's prime minister, the learned historian George Acropolites (1217–1282). Finally, the external dangers faced by the empire during the Palaiologan dynasty, encouraged several Byzantines to turn to their ancestors, seeking a sense of identity that would allow them to face their problems. This rediscovery of classical texts is not limited to a philological approach to these works, but goes further since it became one of the main nuclei of this intellectual renewal (see also Fryde, *The Early Palaeologan Renaissance*).

59 With the plague, which continued after the fall of Byzantium, the weakening of the empire was not only demographic, it was also administrative, political, economic, military, social and therefore scientific especially as the epidemic struck indifferently all social strata. Moreover, the great plague that ravaged the medieval West during the same period also held back the scientific renewal that had emerged in the thirteenth century.

60 Except for the various types of text layouts found in Greek scientific manuscripts, rubrication, division into paragraphs, chapter titles, separation of text and commentary, are some of these techniques that were used, because they offered more fluency and visibility to the medieval reader.

However, even the undeniable slowness that characterized the science of the time and especially the inability of scholars to overcome decisive obstacles, did not prevent some Byzantine scholars from producing original work. We should stress that Byzantine scholars, especially during the last period of their civilisation, did not hesitate to emphasize the *kainotomia* in their ideas, practices, or artefacts, even though we should recognize that they lacked the kind of collective awareness of the ability to innovate seen in the West, especially from 1260.[61]

But in spite of all this, Byzantine science actually existed. If one were to schematize the context, one could say that it was a compromise between a tradition placed under the authority of ancient authors, a worldview dictated by Christianity and an innovation that was established mainly on a speculative basis. Even if the Byzantine knowledge of the world is now considered as mostly unfounded or false, the existence of scientific knowledge in Byzantium at that time is not a mirage, since it was widely documented (see also chapter 1 of this volume).

### 2.2.3 A New Definition of Byzantine Science

Furthermore, if an objective definition of science by its methods or objects is, in the long term, not relevant, we can nevertheless offer a subjective definition of science that would have been admissible from ancient times onward. This formal definition would deal with knowledge deemed certain about the world and would establish a history of mentalities and representations of certainty. Plato distinguished the *doxa*, the opinion, or the *orthos logos*, the right speech, from the *episteme*, defined as a conception of the soul that speech cannot undermine.[62] This criterion of certain knowledge, because it is demonstrated by contemporary reason, founded a series of conceptions ("Greek science," "Byzantine science," "Arab-Muslim science," "Chinese science" etc.) and what they share with current science is the same hermeneutical function. They do not refer to the same objects, methods, or truths, but in each period and in a similar fashion they signify *certain* knowledge, simply because it is demonstrable. There should not be a history of science, but a history of forms of reason or certainty. One could list historical situations that would define not a concept, but a notion whose epistemological status would fall under the purview of

61 In contrast to the term *kainotomia* (καινοτομία), the word *neoterismos* (νεωτερισμός) was also often used by the Byzantines, but it often included negative meanings, like for example rebellion or sedition (cf. Spanos, "Was innovation unwanted in Byzantium?," p. 48).

62 Plato, *Meno* 96c–98d, ed. Burnet; *Timaeus* 29b, 51e, ed. idem; *Respublica* V 477d, ed. Slings.

human and social sciences.[63] In this sense we can speak of a Byzantine science as a constellation of forms of knowledge sharing the same hermeneutic claim to certainty in a given historical context.

In this collective work, we often tend to think according to one cultural convention and reject what is obvious to another. This is not a modern phenomenon. It is not because there is not the same coherence and the same rigour in Aristotle as in the Greek *Physiologus* or in Zosimus of Panopolis for example, that we must exclude them from the scientific literature of the time.

All the authors of this volume agree that there is no close and direct relationship between Byzantine scientific knowledge and ours. Indeed, and without wishing to reiterate my earlier remarks, according to current criteria, alchemy, astrology, arithmology, qualitative physics of the elements, the medicine of humours, the pharmacopoeia founded on the sympathetic virtues of plants, stones or parts of animals are not recognized as scientific disciplines. Even for other fields, the methods are radically different as we shall see. All the same, every author in this volume agrees that anachronism is a capital sin for historians of science. It is indeed anachronistic that almost all the important literature devoted to the history of Byzantine science (and medieval science in general) is evaluated exclusively from a modern point of view. Therefore, it is hardly relevant to emphasize the deficiencies or the originality of the work of this or that Byzantine scholar, because this judgment is set within a wrong perspective.

The genesis of this book sprung from a desire to bring forth a renewed outlook. The book is composed of a total of 13 chapters. The first two (*'Inner' and 'Outer' Knowledge: the Debate between Faith and Reason in Late Antiquity*; *Science Teaching and Learning Methods in Byzantium*) deal with essential points in the understanding of Byzantine science, its methods and its modes of dissemination: the debate between faith and reason in late antiquity and science teaching in Byzantium. The next 10 chapters cover the following areas: logistic, arithmetic, harmonic theory, geometry, metrology, optics, mechanics (chapter 3); theories of vision (chapter 4); meteorology, physics (chapter 5); astronomy, astrology (chapter 6); geography (chapter 7); zoology (chapter 8); botany (chapter 9); human medicine, pharmacy (chapter 10); veterinary medicine (chapter 11); science of warfare (chapter 12).[64] The choice to include the

63 For an application of Jean-Claude Passeron ideas on "universal history," see Inglebert, *Le Monde, l'Histoire. Essai sur les histoires universelles*, pp. 128–30 & 1204–6.

64 To avoid the obvious ontological issues of a scientific study on science and given the fact that the books in this collection aim for a very wide readership, the thematic structure follows a "modern" logic and not a Byzantine one. Each chapter by distinguished scholars offer the most comprehensive and up-to-date history of Byzantine science currently available. Some chapters are more extensive than others because the fields they cover

twelfth chapter is motivated by the need to move away from "technological studies" when it comes to the science of warfare and focus more on the Byzantine's theoretical conception of how to wage war, i.e. a rigorous approach to warfare, to make use of their tactical knowledge and technology to the best of their ability. Indeed, the development of military tactics required extensive knowledge in other scientific fields like geometry, as discussed by George Pachymeres (ἡ δὲ γεωμετρία πρὸς στρατοπεδεύσεις πόλεών, *Quadrivium*, 1.1, l. 37 ed. Tannery/Stéphanou).[65]

Among these subjects, arithmetic, geometry, music and astronomy, were part of the *Quadrivium*[66] or τετρακτὺς τῶν μαθημάτων[67] and as such were taught in school.[68] Of course, other scientific disciplines were taught in Byzantium,

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have been the subject of more important studies. Some of them have only very recently caught the attention of researchers and knowledge about them is still tenuous. In all the chapters, the titles of ancient texts are mentioned in English or common British usage except when it is deemed necessary by the authors to also give the title as it appears in the TLG. We have tried as often as possible to cite a critical edition and an English translation. For quotations from modern texts, we have tried to keep the original language except in rare cases where we offer an English translation. Ancient texts are quoted in extenso with a translation (or at least a long commentary).

65 See also Katsiampoura, "The *Quadrivium* of 1008 and Pachymeres' *Syntagma*," p. 422.

66 The earliest Latin classification and exposition of the liberal arts seems to have been incorporated in the now lost work of Terence Varro (116–27 BCE) entitled *Disciplinarium libri IX*. Varro's compendium of disciplinary or encyclical studies embraced successively: 1. Grammar, 2. Dialectics, 3. Rhetoric, 4. Geometry, 5. Arithmetic, 6. Astrology, 7. Music, 8. Medicine, 9. Architecture. Medicine and architecture were understandably dropped from later discussions of the liberal arts, and there remained the well-known classification later to be designated as the *Trivium* and *Quadrivium*. As J. Weisheipl wrote, "in the Roman theory of education, the seven liberal arts were a preparation for one of the specialized branches of learning: philosophy, medicine or law." (Weisheipl, "Classification of the Sciences in Medieval Thought," p. 55).

67 On this term, see in the prologue of the *Alexias*, in which Anna Komnene says: ἀπὸ τῆς τετρακτύος τῶν μαθημάτων, 1, 1, ed. Reinsch/Kambylis.

68 Depending on the period *Quadrivium* studies could either be of a very rudimentary level, or in contrast be of the highest level, because the study of sciences could in theory be pursued indefinitely. On education in Antiquity and the Middle Ages, see (chronologically): Marrou, *Histoire de l'éducation dans l'Antiquité, Le monde grec*; Legras, *Education et culture dans le monde grec VIII^e^ siècle av. J-C.–IV^e^ siècle ap. J.-C*; Pailler/Payen (eds.), *Que reste-t-il de l'éducation classique ? relire «le Marrou», Histoire de l'éducation dans l'Antiquité*; Hugonnard-Roche, *L'enseignement supérieur dans les mondes antiques et médiévaux : aspects institutionnels, juridiques et pédagogiques*. On higher education, see (chronologically): Fuchs, *Die höheren Schulen von Konstantinopel im Mittelalter*, especially pp. 25–35; Speck, *Die Kaiserliche Universität von Konstantinopel Präzisierungen z. Frage d. höheren Schulwesens in Byzanz im 9. und 10. Jahrhundert*; Moffatt, "Schooling in the Iconoclast Centuries"; Constantinides, *Higher education in Byzantium in the thirteenth and early fourteenth centuries (1204–ca. 1310)*; Mergiali, *L'enseignement et les lettrés*

but probably in a less systematic way at a theoretical level. As rightly pointed out in chapter 2, it is not always easy to reconstruct the history of scientific education.

Finally, chapter 13, entitled *The Occult Sciences in Byzantium*, focuses on several fields which are part of sympathetic knowledge (divination and magic, astrology, iatromathematica, plants and magic stones, alchemy). The reader will find here some areas already analysed in previous chapters but studied from a different angle. The Stoic philosophers introduced the notion of cosmic sympathy in Hellenistic times. According to them, the whole cosmos was like a living body whose parts could not function independently and where the whole depended upon those parts. A "pneuma," a mixture of fire and air permeated the whole world as its soul—sustaining everything. Consequently, the notion of sympathy could apply to any close connection between parts of the world as well as between them and the whole world. On this basis, we can understand the connections between Mega-cosmos (celestial sphere, fixed stars and planets) and Micro-cosmos (man) as expressed in Astrology and the Iatromathematica (or Medical astrology). Furthermore, the interconnections of Mega-cosmos with animals, plants and stones/minerals based on special qualities of these species provide the link between them and man.

A man was considered as endowed with reasonable power and psychic qualities that contributed to the structure of his whole social persona. Men's anxiety for their future, especially fears regarding illness and death, forced them to invent divinatory and magical practices transmitted through the centuries from one generation to another.

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*pendant l'époque des Paléologues* (1261–1453); Karzis, *Η παιδεία στο μεσαίωνα. Δυτική Ευρώπη: Εκπαίδευση σε μοναστήρια και ναούς, Βυζάντιο: Εκκλησιαστική και θύραθεν παιδεία, Ισλάμ: Ο ελληνογενής πολιτισμός που φώτισε την Ευρώπη*; Tsampis, *Η παιδεία στο χριστιανικό Βυζάντιο*; Markopoulos, "De la structure de l'école byzantine. Le maître, les livres et le processus éducatif"; Tihon, "Les sciences exactes à Byzance"; Chatzikakidis, *Οι ανώτατες σχολές θεωρητικής παιδείας στην πρώιμη Βυζαντινή Περίοδο, 4ος–8ος αι. μ.Χ.*; Schamp, "Du verbe au Verbe. Considérations sur le renouveau de l'enseignement à Byzance au IX^e siècle"; Loukaki, "Le profil des enseignants dans l'Empire Byzantin à la fin de l'Antiquité tardive et au début du Moyen âge (fin du VI^e–fin du VII^e siècle)"; Markopoulos, "L'éducation à Byzance aux IX^e–X^e siècles: problèmes et questions diverses." On Byzantine intellectuals and intellectual life in the Empire in general (with references to the education), see the recent work by Pontani, "Scholarship in the Byzantine Empire (529–1453)." There are also cases in which the "classical" *Quadrivium* was not followed (as well as the *Trivium*). Thus, according to Theophanes Continuatus, Leo the Philosopher (or the Mathematician), appointed as head of a school close to the Magnaura (κατὰ Μαγναύραν, 4.26, p. 185, ed. Bekker) created by Bardas between 843 and 855–856, entrusted the teaching of geometry to his disciple Theodore and that astronomy to another disciple, Theodegius (Cometas was in charge of grammar and Leo himself of philosophy).

Men tried to unite themselves with the cosmos either to receive knowledge or to use cosmic forces both in Magic and Divination. Men used their mental and psychic powers to grasp the meaning of omens or other special divinatory signs and explain them. Consequently, divinatory and magical practices are possessed of a strong psychological power that is present but cannot be measured. But is Psychology a science? Psychological phenomena (fear, anger, love, hate and other) cannot be measured in themselves; only their effects on human physiology can be measured. If we consider Psychology to be a science today, we should accept Divination and Magic as sciences of the remote past.[69]

Do the different chapters presented here cover all the areas that the Byzantines considered to be scientific? To offer an answer encompassing the entire duration of the Byzantine civilization (4th–15th C.) is almost impossible. For example, did Theodore Meliteniotes consider astrology to be a serious field and fit to be part of the sciences? Most likely not. On the other hand, at other times and for other scholars, astrology was without a doubt part of the scientific domain. Apart from this difficulty, it should be noted that there were no standards in Byzantium for clearly defining scientific fields.

We cannot rely on the *Quadrivium* to distinguish what was or was not scientific. Otherwise what should we do with medicine (human and veterinary), pharmacy, zoology or geography for example? The answer to this question is perhaps to be found in the recognition by Byzantine society (and therefore the

69 Our decision to include occult sciences and offer new perspectives on the subject, builds on the many studies on Byzantine science that have also discussed their importance in the history of science. H. Hunger for example did not exclude "pseudo-science" or "occult science" from his monumental book. In the Introduction of Ch. 9 (Mathematics and Astronomy [Astrology]) he refers to the rich astrological literature published as *Catalogus Codicum Astrologorum Graecorum* in 20 (I–XII) volumes and continues with the theurgic literature of Neoplatonists and the various methods of divination. He exposes in detail all information regarding the astrological writers and literature during the three periods of Byzantine history (Hunger, *Die hochsprachliche profane Literatur der Byzantiner*, vol. 2, pp. 223, 228, 232–36, 238–39, 241–43, 251). His two-page Introduction of Ch. 10 (Physical sciences, *ibidem*, pp. 263–64) is devoted to the notion of Stoic sympathy and the various aspects of theurgy (priestliche Wissenschaft). In the particular part on botany he includes the practices of root-cutters, the close relations between medicine and magic expressed in plant astrology and in medical-pharmaceutical recipes. In Mineralogy he refers to various treatises on stones as *Orphic Lithica*. Finally, he devotes a particular part in Alchemy (*ibidem*, pp. 271, 274–75, 277, 279–82). On the other hand, K. Vogel included a partial chapter (XII) on "Superstition and pseudo-science" and another chapter (XIII) on "Technology" where he exposes the technical treatises of Greek alchemical writings (Vogel, "Byzantine Science," pp. 296–99, 301).

social place) of their representatives. However this line of thought is also difficult to exploit because of the limited information that is available to us.[70]

The present volume is intended to be a synthesis of the main, if not the only, Byzantine scientific domains and despite the presentation of often unpublished documents, it addresses a wide academic audience. Any synthesis implies a preliminary selection. It is obvious, for example, that a history of science cannot aim to account for all the technical details that a scientist might need to satisfy very specific requirements. The result would be incomprehensible. Also, alongside the general history of science, there will always be room for more detailed historical cases, focussing on a further study of an offshoot of scientific thought. The collective work that was carried out to produce this book led to a first international symposium on the development of scientific knowledge in Byzantium, which took place in Paris (19–20 Oct. 2018). Our combined effort has led to creating an international research network. Its aim is to offer new perspectives and to formulate, through the study of Byzantine science, a Byzantine *turn*.

70 In the recent publications on the history of science and intellectual life in ancient Greece, Rome and/or in Byzantium (among others: Kaldellis/Siniossoglou [eds.], *The Cambridge Intellectual History of Byzantium*; Lindberg/Shank [eds.], *The Cambridge history of science*; Irby-Massie [ed.], *A companion to science, technology, and medicine in ancient Greece and Rome*; Radici Colace/Medaglia/Rossetti [eds.], *Dizionario delle scienze e delle tecniche di Grecia e Roma*), the scientific editors added other fields that were not selected for this volume, such as embryology, hydrology, architecture, logic, physiognomy, hydrostatics. A number of these fields are technological which the current volume only covers indirectly through certain chapters, in particular the science of warfare.

CHAPTER 1

# 'Inner' and 'Outer' Knowledge: the Debate between Faith and Reason in Late Antiquity

*Hervé Inglebert*

We have been rightly reminded in the general introduction that science, in its current sense does not equate to ancient forms of knowledge. But there was such a thing as 'Byzantine science' which covered all the forms of knowledge from an era that shared a similar appreciation for 'certain' knowledge according to the criteria of reason of that time.

If the criteria of current science are clearly different from those of ancient forms of knowledge, we must however distinguish between Graeco-Roman knowledge and Arab, medieval Latin or Byzantine forms of knowledge and between the latter. We will focus on the late antique knowledge matrix which gave birth to Byzantine science.

This body of knowledge can be divided into three groups. The first is the partial reception of Graeco-Roman knowledge in late antiquity and in Byzantium, whether it was in Greek, Latin or Syriac, while Persian and Indian influences contributed to Muslim knowledge. The second group included specific contributions from late antiquity, its novelties (e.g. veterinary medicine or Philoponus' theory on the movement of celestial bodies) and its compilations of previous forms of knowledge (Timotheus of Gaza's treatise *On animals*, *c.* 500 or the *Ethnika* produced by the grammarian Stephen of Byzantium under Justinian) both of which were disseminated over the next thousand years. The third group is specifically Christian, as they had become the majority in the fifth century and were especially concerned by the relationship between Graeco-Roman knowledge and revealed scripture. This lead them to discuss the relationship between faith and reason which is the focus of our paper.

Two anachronistic issues can be dismissed from the outset. First, the eighteenth-century debate between religion and science. This modern perspective did not exist as such in late antiquity. The second issue is the nineteenth-century opposition between 'modern' scientific truth and pre-scientific error. Based on later advances in scientific knowledge, we know that late antique knowledge was mostly erroneous, but it was believed to be true because it had been demonstrated or was plausible according to the knowledge of the time.

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However, there was a debate in late antiquity between faith (*pistis*) and reason (*logos*). It was crucial because it clarified the various forms of 'certainty' in late antiquity, and defined subsequent frameworks in the development of Byzantine knowledge. This debate was not related to methodological upheavals or new discoveries, but to a hermeneutic recontextualization linked to the Christianization of knowledge. Indeed, one of the novelties of Christianity, following Judaism, was to assert that texts deemed to be revealed or inspired conferred a status of certainty to knowledge since they were guaranteed by a divine authority.

These certain forms of knowledge—because of their divine origin—, were called by Christians 'inner' knowledge [or 'our knowledge'] as opposed to less certain or even doubtful forms of knowledge because of their human origin, which they called 'outer' knowledge. As the latter often consisted in philosophers and scholars, considered to be 'heathens,' the epistemological debate was also religious, whereas between Christians it was exegetical. This debate, which was crucial between the third and sixth centuries, became less important with the Christianization of society and the petrification of traditions. This is why, even if late antique scholars were not all Christians and if few aspects of late antique knowledge were based on biblical texts, the status of knowledge on the world was essential at the time.

## 1 Christian Exegesis of the Bible (Second–Fifth Centuries CE)[1]

Typological exegesis was favoured during the first two centuries CE because the meaning of a text could be attributed to one of a later period. It enabled Christians to assert that biblical prophecies had been fulfilled in the person of Jesus of Nazareth and to interpret the text of the Old Testament as an image of the contemporary Church. It also helped to refute the literal reading of the Jews the way in which certain Gnostics rejected the heritage of the Old Testament. Indeed, second century Gnostics often picked and chose from Scripture passages they considered to be authentic and, if necessary, filled in the blanks with other passages they considered to be revealed. This body of texts was then commented allegorically which meant the meaning of the text could be understood by analogy. Against these infinite interpretative possibilities, the Christians of the Great Church fixed the biblical canon, insisted on the lineage of

1 Simonetti, *Lettera e/o allegoria.*

the apostolic tradition (Irenaeus of Lyon, *c.* 180) and chose typological exegesis, insisting on the parallels between the Old and New Testaments.[2]

Around 200, in Alexandria, Clement, an Athenian philosopher turned Christian, reconnected with Philo's Jewish-Hellenic tradition, integrating physical and psychological allegories into biblical exegesis, while using typological exegesis to oppose the Gnostics.[3] Allegorical exegesis had two advantages: it limited the Jewish input in Christianity by reducing the importance of literal readings and adopted certain mental processes that were well-known among scholars of the *paideia*. Origen, another Alexandrine, was of the same lineage as Philo and Clement.[4] While preserving literal exegesis, based henceforth on a rigorous biblical philology of the Hexapla and developing moral exegesis, he favoured especially allegorical exegesis which, according to him, was the only approach in line with the prophetic Spirit. Because the biblical text was considered to be a truth with a divine seal, it was legitimate for Origen to apply to it an allegorical interpretation according to Greek or Philonian norms (numerical symbolism, etymology, physical or psychological explanations).[5]

But Origen's position met with serious resistance. In those days, bishops imposed their authority on Christian communities against prophets and confessors of the faith; they could not accept exegetical methods that required such a level of philological and philosophical preparation that the interpretation of the Bible could only be entrusted to specialized *didaskaloi*. The less technical typological exegesis suited them far better and strengthened their authority because they were able to make parallels between Old Testament priesthood and Christian clerics. Moreover, some of Origen's theological positions conflicted with tradition, which explains why he was ousted from Alexandria, and why, as early as 260, some became suspicious of allegorical exegesis which they thought disseminated heretical ideas. Nevertheless, it endured, because it offered appropriate meanings to obscure or scandalous biblical passages; it was still used around 300, by Methodius of Olympus.[6]

Allegorical exegesis was Stoic in origin, and therefore philosophical.[7] It is only because there was a strong tradition of philosophy in Alexandria,[8] a rarity in antiquity, that this hermeneutical pattern was maintained over many centuries and that it was accepted as self-evident by Philo, Clement or Origen. There

2 Dorival, *Exégèse juive et exégèse chrétienne*.
3 Tardieu, *Alexandrina*. Dawson *Allegorical Readers*.
4 Le Boulluec, *Alexandrie antique et chrétienne*.
5 Harl, *Le déchiffrement du sens*.
6 Pépin, *La tradition de l'allégorie*.
7 Pépin, *Mythe et allégorie*.
8 Watts, *City and School*.

was another way of understanding the Bible: there existed in Syria, and especially in Antioch—which boasted a famous public school of rhetoric[9] and a strong Jewish tradition that favoured a literal historical and non-rabbinical reading of the biblical text.

Around 180, Theophilus of Antioch used it to reassert the continuity of the history of salvation, from the patriarchs to the Church. Yet, it was not until Eustathius of Antioch, around 311–325, that allegorical reading was explicitly rejected. If his desire for textual scrupulousness, which sometimes meant going back to the Hebrew text, was not new (Origen and Lucian of Antioch had followed the same path), he understood the meaning of the sacred text in a historical way, within the context of the alleged era in which the text was produced. In his view, the historical literal meaning could exhaust the meaning of a biblical passage; thus, any typological reading, or worse, allegorical, was unfounded. This approach made space for the neo-Platonic philosopher Porphyry's historico-critical analysis which he developed in his *Against Christians* (about 275), and thus positioned Christians as serious interlocutors in the debate between learned elites. Moreover, this reading of the biblical texts distinguished the accomplished prophecies in the history of Israel from the Messianic ones which only concerned Christians. This literal approach of the text, which built on a historicization of the Bible and a progressive teaching of the divine word, meant it was mostly useless for contemporary Christians.

Subsequent scholars had to position themselves regarding three exegetical options, typological, allegorical and historicizing. Eusebius of Caesarea, heir to Origen's library and ideas, combined all three readings. After his example, in the fourth century, proponents of Origen's allegorical exegesis, mainly Cappadocians (Basil of Caesarea, Gregory of Nazianzus, Gregory of Nyssa), decided to use literal exegesis when allegorical exegesis supported positions that they considered heretical.[10] But their contemporaries Acacius of Caesarea and Eusebius of Emesa further developed the ideas of Eustathius of Antioch, followed by Diodorus of Tarsus and Theodore of Mopsuestia. After 400, there were a few partial convergences, Theodoret of Cyrus was not always a literalist, nor was Cyril of Alexandria always an allegorist.[11]

But the ongoing theological debate hardened exegetical positions. Indeed, in 431, Nestorius, who was priest of Antioch before he was elected bishop of Constantinople, was condemned as a heretic at the Council of Ephesus, a

9 Cribiore, *The School of Libanius*.

10 De Margerie, *Introduction*.

11 De Lubac, *Exégèse médiévale*.

decision spearheaded by Cyril of Alexandria. Beyond the geo-ecclesiastical and theological rivalries between the two seats, this decision had consequences on Antiochian exegesis, which was suspected of being at the source of the heresy. 'The Persian School' from Edessa, which maintained, in Syriac, the Antiochian tradition of Diodorus of Tarsus and Theodore of Mopsuestia was closed down in 489 and its teachers retreated to Nisibis,[12] in Sassanid territory, where the Eastern Church shared this reading of the Bible (because of this it was called 'Nestorian' by the Roman Orthodox).

## 2 The Relationship between Christian Faith and *Paideia* (150–340 CE)

From the first century CE, the use of Greek by Christians led them to combine a dual Hellenic heritage based on the one hand on the Biblical and Jewish-Hellenistic Septuagint as well as Philo's and Flavius-Josephus' writings; and on the other hand, the Graeco-Roman *paideia* in which most Christian scholars were trained. Graeco-Roman schools were necessary but problematic because they were suspected of paganism and of leading to heresy. They were unknown to most Christians, for social reasons (they were expensive), geographic and cultural (there were fewer traditional schools in Aramaic speaking regions) or religious (Jews and monks favoured the biblical tradition). This is why from the second century onwards, Christians held conflicting opinions about Graeco-Roman knowledge, which must be contextualised in time, regional traditions and social background.

From 150 to 180, some considered that all truth being in conformity with the divine order, Graeco-Roman knowledge was compatible with the Bible. Justin from Nablus, 'philosopher and martyr,' was the first to present the argument that there could be no contradiction between the human *logos* and the divine *Logos*. Human reason was inspired by the Word of God, and since truth was unique, it was necessarily Christian: 'everything they (*the pagan philosophers*) taught us that was good belongs to us Christians (*II Apology* 13.4). There was no need for a distinction between Greek *episteme* and Christian *gnosis*, since Heraclitus and Socrates were Christians. This rationalizing Christianity was also promoted by Athenagoras, an Athenian philosopher. The debate focussed mainly on the status of Stoic morality (seductive, but needed to be separated from the materialism of the school of the Porch) and Plato's anthropology (who founded the idea of an immortal soul, but it could not be thought as

12 Vööbus, *History of the School of Nisibis*; Becker, *Fear of God and the Beginning of Wisdom.*

eternal or subject to reincarnation). Furthermore, philosophy had a much broader meaning than its three Greek components (physics, logic and ethics). One can add the knowledge of *paideia* (grammar, rhetoric, erudition) as a propaedeutic to philosophy. Thus, the issue potentially extended to the entire Graeco-Roman tradition, even if Christian writers only retained from it what they approved.[13]

This very stoic certainty of the harmony between human logos and divine Logos was not retained in later years, because it favoured Gnostic speculations. Towards 180, Tatian (*Address to the Greeks*) defended the knowledge and philosophy of 'Barbarians,' including Christians, against those of the Greeks, considered useless, even if he mastered their knowledge perfectly. In the same period, Theophilus of Antioch (*To Autolycos* 3:17) opposed the 'certainty' of divine knowledge to the 'uncertainty' of human knowledge. And, Irenaeus of Lyon was the first to assert that philosophy was the mother of all heresies. This position was then revived by the Pseudo-Justin (*Exhortation to the Greeks* 9) and formulated as a theory around 230 in the *Philosophumena*, disseminated under the authorship of Hippolytus of Rome. At the end of the second century, Hermias wrote his *Satire on pagan philosophers*, and Clement of Alexandria mentioned that some Christians in his time thought philosophy was a work of the devil (*Stromata* 1, 18, 3), an idea that persisted until the fourth century (*Pseudo-Clementine homilies* 4. 12–13).[14] This is why the *Didascalia of the Apostles*, written in Syriac in the first half of the third century in Syria, asserted that the Bible was enough evidence to define Christian culture and rejected Graeco-Roman knowledge to impose a strictly biblical form of knowledge (2.6.1–6):

> Keep far then from all the books of the heathen. For what do you have in common with foreign words or with false laws or prophecies, which also easily cause young people to wander from the Faith? What are you lacking in the Word of God that you cast yourself on heathen myths? If you wish to read the tales of the fathers, you have the Book of the Kings, or of wise men and philosophers, you have the Prophets, amongst whom you will find more wisdom and intelligence than among wise men and philosophers because they are the words of God, who alone is wise. If you desire songs, you have the Psalms of David; to know the beginning of the world, you have the Genesis of Moses; laws and commandments, you have the Book of the Exodus of the Lord our God. Therefore stay away from all foreign things that are opposed to them.

13 Pouderon/Norelli, *Histoire de la littérature grecque chrétienne*, pp. 651–759.

14 Pouderon/Doré, *Les apologistes chrétiens et la culture grecque*.

Faced with this distrust, the Alexandrians had to justify the Christian use of philosophy after 200 and this could only be achieved by giving it a subordinate position.[15] The fact that philosophical truths belonged to the Christian truth was explained by the idea (of Jewish-Hellenistic origin) of the theft by demons or Greeks (Clement, *Stromata* 5.14.97) of an earlier biblical tradition, or by the fact of a human logos shared by all and partially able to understand God (the idea of Stoic origin already present in Justin's works). The use of Greek knowledge by Christians was founded on the allegorical interpretation of certain biblical passages. The theme of the Hebrews taking goods from the Egyptians during the Exodus, a secondary theme in Philo, was applied to Christians by Irenaeus of Lyon (*Against the heresies* 4.30.1–4) to justify the use of certain forms of knowledge from Graeco-Roman culture, and this idea was revived later by Origen (*Philokalia* 13) and Gregory of Nyssa (*Life of Moses*). Other metaphors followed the same path: Biblical ones, of Sarah's servant Agar (Clement, *Stromata* 1.5.30–32), or the son of Moses and Zipporah who was to be circumcised (Gregory of Nyssa, *Life of Moses*); or secular ones regarding the money changer who checks his coins (Clement, *Stromata* 6: 81.2) and bees feeding on flowers and selecting which ones to make honey from (Basil of Caesarea, *Address to young men on the right use of Greek literature* 4). But this approach only made sense for the proponents of allegorical exegesis.

Then, they had to show the usefulness of philosophy, which seemed superfluous and incomplete compared to biblical truth. The main argument was that Graeco-Roman *paideia* was a *propaideia*, a preparation for divine truth.[16] Philo of Alexandria had already subordinated *paideia* to biblical wisdom in the *De congressu eruditionis gratia*. In doing so, he had adapted to Judaism the common idea of *paideia* as an introduction to philosophy, an idea expressed by pagan authors like Plutarch (*De audiendis poetis*) for whom literary *paideia*, essentially poetic, was condoned (against Plato, but in agreement with the Stoics) to access philosophy. This hierarchy justified the use of a part, which varied according to different authors, of Graeco-Roman knowledge as a preparation for Christianity.[17] Clement of Alexandria dedicated his first *Stromata* to explain that Greek culture, and mainly philosophy, was a stepping stone to Christian faith and a tool for strengthening it. But if logic could be used to demonstrate faith, one had to be wary of sophistry which produced false opinions, rhetoric that embellished errors, and eristic that gave rise to vain quarrels. Thus, Clement, far better than Justin who was inclined to recognize the equal value

15 Alexandre, *La culture grecque, servante de la foi.*

16 Morlet, *Les chrétiens et la culture*

17 Dorival, *Les chrétiens de l'Antiquité.*

of biblical teaching and philosophical doctrines, the model of later Christian scholars, saw Greek *paideia* as just a Christian *propaideia*.

Finally, it could also be said that Greek philosophy was a means to better understand the Bible and to deepen the Christian faith. Clement acknowledged that secular culture was not indispensable to salvation, for among certain Christians, with little or no education, divine wisdom acted alone. But he thought that reason could prepare the minds and strengthen the faith through its arguments. He insisted (*Stromata* 1.6.79–80) on the interest of arithmetic, geometry, music and astronomy (the *mathemata* of the future *Quadrivium*) for Christians and mocked (1.6.93–94) the believers who criticised *episteme*. In his view, the tension between Hellenic culture and Christian faith, between human philosophy and divine wisdom, only existed in the minds of people who did not master both sides. Yet, two aspects require further explanation. First, for Clement, most of Greek culture, its literature and poetry was futile (after Plato who had driven poets out of his ideal city): only Plato's philosophy (which included the *mathemata*) could lead to divine wisdom. Secondly, Moses' philosophy was of different order, including four parts (*Stromata* 1.28.176.1–2): the historical and legislative (which together formed the ethical), the hierurgical (religious rituals) and the theological (metaphysical). Christian philosophy, which aimed for Goodness and Truth, did not reside in geometry, in music, in astronomy, or in *enkyklios paideia* (1.19.93.4–5).[18]

Origen followed this path of intellectual Christianity. For him, faith was the way for simple people to reach the truths that the wise understood better than them. He distinguished (*Homily on Genesis* 11.2) the teachings of God's Law from 'outer' knowledge—literature, geometry, dialectics—but defended secular knowledge as constitutive of Christian wisdom. Clement saw Greek philosophy as God's gift to the Greeks (*Stromata* 6.42–43), as the Law was God's gift to the Jews. Christianity was for Clement the perfect accomplishment of these two incomplete approaches. Origen was more circumspect about the value of philosophy, which he sometimes viewed as a preparation for Christianity but acknowledged also the possibility that Christ's message might be tainted by it. Nevertheless, he thought that Christian faith was compatible with the common notions that were present in the reasonable part of the soul (*Against Celsus* 3.40).

Eusebius of Caesarea attempted to demonstrate in his *Preparation for the gospel* that the conversion to Christianity was the necessary conclusion of a reasoning based on history. For him, Greek philosophy derived from Jewish philosophy (a variation on the Graeco-Roman theme that made Plato a pupil

18 Young, *Biblical Exegesis*.

of the Egyptians) and was therefore inferior to it (*Preparation for the gospel* 10.1.1–4 and 11.28.19). He also pointed out the dissensions between philosophers on the nature of the world, which, according to him, contrasted with the unity found in the biblical tradition. He showed the common points between biblical truths and Platonic theories (*ibidem*, 15.3–13), but explained how useless the knowledge of the *mathemata* was for salvation. Finally, he defended Socrates' reduction of philosophy to ethics (15.62.1–6) and concluded that it was necessary to be a Christian. Eusebius distinguished secular knowledge about the world, which he did not reject, from the biblical-Christian truth, which included sacred and ecclesiastical history.

## 3 The Relationship between Christian Faith and *Paideia* (360–450 CE)

In the 360s, the debate on the links between Graeco-Roman culture, pagan religion and Christian religion took a far more dramatic turn. The Emperor Julian wanted to restore pagan cults to their former glory, before Constantius II's ban in 356. Julian added also a cultural component to his religious policy: in 362 he issued an edict forbidding Christians to teach, claiming they were not competent to comment on Graeco-Roman texts that referred to gods they did not pay homage to.[19]

'Galilean' teachers could only comment on the gospels in their churches and had to let the pagan teachers teach classics. This link between Greek culture and Hellenic cults was a legacy of Porphyry, which had been endorsed by Christian monks and ascetics. But most literate pagans found the extent of this edict too excessive, as well as most Christian scholars who saw it as an offensive manoeuvre. While Christian students were not banned from Graeco-Roman schools and could pursue the training which was necessary for their career, Christian culture was relegated to the rank of a barbaric subculture, unworthy of being compared to Graeco-Roman culture. This explains the reaction of the two Apollinaris of Laodicea, father and son, who transposed parts of the biblical writings into Greek poetic models, to prove that Christians did not have to be embarrassed by their doctrine which could also be presented in a noble and beautiful way. The death of Julian in 363 caused his edict on schools to be rescinded and the attempt to create a Christian textual corpus based on Graeco-Roman models was abandoned. But the question of the relationship

19 Bouffartigue, *L'empereur Julien*.

between Hellenic-pagan culture and Christian culture had been presented so brutally that it had to be addressed.

Gregory of Nazianzus adopted a strictly cultural point of view. For him, Hellenism was a common inheritance that was necessary to all and he found it shocking that Julian had tried to make it the sole property of pagans (*Discourse* 4.5 and 100–109 = *Discourse against Julian* 1). And if he polemicized (*Discourse against Eunomius* 29.21) against the application of Aristotelian categories to explain the divine mystery of the Trinity, piety and *enkuklios paideia* were, according to him, necessary to achieve human perfection (*Discourse* 43.12). Thus he wrote about *paideia* (*Discourse on Basil* 43.11):

> Education is the first gift available to us; not only the education that is ours and disdains elegance and rhetorical ornaments to focus only on the salvation and beauty of ideas, but also that of the outside [that external culture], that most Christians reject with disgust, judging it treacherous, dangerous and keeping us afar from God.

Basil of Caesarea, inspired by Plutarch and Clement of Alexandria, had a more nuanced position. He wrote, around 365, a treatise aimed at young Christian scholars, called *To young men on the right use of Greek literature*. They could be trained in the Graeco-Roman schools and study poets and rhetoricians who, from a religious perspective, were Hellenes, i.e. pagans. For Basil, secular culture helped to train the mind and enable it to grasp the meaning of obscure biblical texts.

Nevertheless, one had to sort and choose, like bees, discard the negative, scandalous or seductive aspects of poets for the benefit of the truth. In this treatise, Basil recaptured the distinction that pervaded the Byzantine era, between 'outer' wisdom, *exo sophia* (or *thurathen sophia*, wisdom of the vestibule), of human origin, the heritage of a non-Christian past, which had a practical value but none for salvation, from 'our philosophy,' an 'inner' knowledge or wisdom, of divine origin and based on biblical revelation, in other words, Christian teaching. But the use of pagan knowledge by Christians was useful and legitimate, just like the Hebrews had carried Egyptian spoils to the Promised Land. Basil and Gregory's theological fame helped to preserve this position, both utilitarian and humanistic, which was revived by Synesius of Cyrene around 400.

But this position was not the only one, for in the same decade other discourses emerged, far more hostile to Graeco-Roman culture. One of these hardened the traditional Syrian discourse against the culture of *paideia*. It was

particularly developed by Epiphanius of Salamis[20] who wrote two treatises against heresies, the *Ancoratus* (*Anchor*) and the *Panarion* (*Box of remedies*, hinting at Hellenic-Pagan diseases), in which he developed two further theses. The first asserted that Hellenism was one of the four primordial heresies that structured the future of humanity understood as a universal history of the doctrine of salvation and heresy. The second set out a series of propositions concerning the knowledge of the world (and not on the dogmas of the faith), considered to be 'certain,' in the historical, geographical and ethnographic fields, because they were based on a literal reading of the Bible.

Another discourse against secular culture was spearheaded by the monks. Many among them were illiterate in the ancient sense of the word (they had not attended the school of the grammarian), or had learned to read by deciphering the Psalms, even if some of them were great scholars. In the first monastic biography, that of Anthony, written around 360 by Athanasius of Alexandria, the father of monks was presented as a person who could not read or write, which he was not, in order to insist on his wisdom of divine origin. Then, the topos of the monk prevailing over the pagan philosopher by his *parrhesia* (freedom of speech) became a hagiographical cliché. More specifically, around 400, the ascetic performances of Egyptian or Syrian monks were understood as proofs of a wisdom that went beyond that of the pagans. Monachism appeared as the true Christian philosophy[21] and the monk as the true Gnostic, according to Evagrius Ponticus.

Theodoret of Cyrus was both the author of the *History of the monks of Syria*, who developed the ideal of the ignorant and wise monk, and, before 437, of the *Cure for Hellenic Diseases*, which revived in its title the idea of Epiphanius of Salamis, the last apologetic treatise against pagans-Greeks. Theodoret developed the idea that belief was the primary mode of knowledge for the human spirit and that knowledge could only be based on Christian faith.[22] He broke off from the apologetic tradition that went from Justin to Eusebius of Caesarea via Athenagoros, Clement and Origen. In his view, the debate was no longer between Christian faith and Greek *logos*, but between Christian faith and unbelieving Greek culture. No longer was faith irrational, it was incredulity that made the world unknowable. To the pagan reproach of *pisteuein monon*, Theodoret answered *pisteuein proton*: there was no knowledge without faith (*Cure for Hellenic diseases* 1.92–93). This reduced the distance between the faith of simple folk and Christian scholars. However, Theodoret accepted much of the

20 Pourkier, *L'hérésiologie chez Épiphane de Salamine*.
21 Brown, *Power and Persuasion*.
22 Guinot, *L'exégèse de Théodoret de Cyr*.

secular culture, compatible with the Bible, and did not impose to confine Christians to a culture based only on the Scriptures. For him, as for Origen or Eusebius, Christian faith and *paideia* were not irreconcilable, but hierarchical: beyond the traditional assertions on knowledge about the world which held no importance for Christians (*ibidem*, 4.25–30), Theodoret, close to Basil of Caesarea's position, permitted the use by Christians of an expurgated Graeco-Roman tradition (*ibidem*, 1.127):

> We also, who have taken in hand the works of your poets, your historians, your philosophers, we first lay on one side what is injurious and manipulate the rest for the knowledge of teaching (*didaskalias episteme*). We apply to you this remedy that acts as an antidote (Translation Thomas Halton: Theodoret of Cyrus, *A Cure for Pagan Maladies*, New York, 2013.)

## 4 Christian Salvation and Knowledge about the World

The absence of a systematic scientific (in the modern sense) method in antiquity, implied that there were few certainties in knowledge about the world. Plato had already distinguished what humans found plausible from divine truth regarding the knowledge of the world (*Timaeus* 29c, 68d, 72d–e). Certainly, the Hellenistic and Roman eras had inventoried the world, the inhabited earth (Eratosthenes, Strabo, Ptolemy), the human past (Diodorus of Sicily, Nicolas of Damascus), the human body (Galen), the sky (Ptolemy) and pharmacopeia (Dioscorides). Greek knowledge, translated and collected in Latin by Pliny the Elder and others, seemed to have come to a close.

But this description of the world, made of contradictory postulates and punctual erudition, remained incomplete. Doxographies easily showed the contradictions between scholars or philosophers on the causes of the flood of the Nile or earthquakes, or *mirabilia* to scientific general principles.[23]

It is not surprising, therefore, that Christians held similar views, since for them truth and the sovereign good were not of this world: terrestrial knowledge was uncertain and certainty was only conveyed by divine revelation. The author (Pseudo-Hippolytus of Rome) of the *Elenchos* was not irrational when he used the writings of the sceptic philosopher Sextus Empiricus to refute astronomy and thus ruin the claims of heretics using astrology. He was simply a humanist in the ancient sense, refusing to waste his life in vain investigations. The attitude of Christians towards ancient knowledge was therefore not obscurantist, it was the same as most philosophers for a long time, even if it was

23 Candidi, *L'erudito, il filosofo, il curiosus*.

reinforced by an evangelical distance to the world, in which Christians were to live without belong to it. For the realization of the self, that Christians called salvation, knowledge about the world was as useless as rhetorics or glory.

Basil of Caesarea could therefore write (*Homily on the Hexaemeron* 9.1):

> The authors who have written about the nature of the world (*peri kosmou*) have discussed at length the shape of the earth. If it be spherical (*Plato, Aristotle, Stoics*…) or cylindrical (*Anaximander*), if it resembles a disc and is equally rounded in all parts (*Leucippus*), or if it has the forth of a winnowing basket and is hollow in the middle (*Democritus*); all these conjectures have been suggested by cosmographers, each one upsetting that of his predecessor. It will not lead me to give less importance to our story of the creation of the universe, under the pretext that the servant of God, Moses, is silent as to shapes; that he has not said that the earth is a 180,000 stadia in circumference (*measure of Poseidonios mentioned by Ptolemy*); that he has not measured into what extent of air its shadow projects itself while the sun revolves around it, nor stated how this shadow, casting itself upon the moon, produces eclipses. He has passed over in silence, as useless, all that is unimportant for us. Shall I then prefer foolish wisdom to the oracles of the Holy Spirit? Shall I not rather exalt Him who, rather than filling our minds with such vanities, regulated all Scripture in view of the edification and salvation of our souls?

This did not prevent Basil from accepting the astronomical model of the scholars of his time, that of the spherical cosmos. However, Christian scholars were not Graeco-Roman philosophers because they believed they held a certain truth in their hands for it was contained in the Bible. Once they had asserted that the Christian scriptures contained a higher truth than the opinions of philosophers, and imposed the supremacy of the divine Logos on human *logoi*, the Christians had two solutions. The first was to present the profane as demonic, to reject it and hold the Bible as the sole certain source about the world. The second was to think that secular knowledge existed between Christian truth and demonic or heretic error. Knowledge about the world was useless to achieve what was essential, spiritual salvation, but they could be useful to better understand the Bible or defend Christian doctrine. It was the position of Basil of Caesarea (*Homily on Hexameron* 1.8) or Theodoret of Cyrus (*Cure for Hellenic diseases* 4.25–30).

## 5 Knowledge Related to the Bible

To understand the relationship between 'outer knowledge' and 'inner knowledge,' which combine exegetical, cultural and sociological issues, one must specify what were the branches of knowledge involved.

Most of the Christian biblical knowledge about the world came from Genesis, and particularly from the beginning of this text on the creation of the world (creation in six-day or *Hexameron*) and Genesis 10, on the genealogy of the descendants of Noah and their dispersion after their failure in building the tower of Babel (the *Diamerismos*). Using the *Hexameron* meant one could speak about cosmology (the origin of the world), cosmography (the world's shape) and astronomy, but also potentially minerals, plants and animals, then anthropology with the creation of Adam and Eve. Based on the *Diamerismos* one could discuss issues of ethnography and geography. One ought to add to this the continuous biblical chronology starting from Adam which was used as the backbone of historical discourses. These were the fields of biblical knowledge which could relate to Graeco-Roman knowledge: they were juxtaposed to, combined with or contrasted to them. The diversity of biblical information, but especially the variety of theological contexts explains the differential treatment of this knowledge. Some aspects of the Hexameron were hardly developed, even though the divine creative dimension might have given rise to long catalogues of rocks, plants and animals emphasising their qualities or therapeutic aspects.

*Mirabilia* were used occasionally to challenge secular knowledge, to argue for the resurrection of the body or reassert the greatness of the Creator about certain remedies, but it did not consist in an organised scientific corpus. The few treatises that might have come close to it, like the *Physiologus*, the first version of which dated from around 200 and which dealt with the properties of certain minerals, animals and plants,[24] or the *Of the twelve gems* by Epiphanius of Salamis (*c.* 394) on the High Priest of Jerusalem's breastplate jewels,[25] are essentially allegorical and moralistic. It amounts merely to a juxtaposition of Graeco-Roman (in the case of the *Physiologus*) or biblical (Epiphanius) knowledge and Christian symbolic interpretations.

Other areas offered better grounds to compare Christian and Graeco-Roman knowledge like ethnography: scholars compared the list of 70 or 72 descendants of Noah to Greek ethnographic knowledge that had accumulated since the time of Hecataeus and Herodotus. They tried to harmonize the

24 Lazaris, *Le Physiologus grec*.

25 Nieto Ibanez, *El lapiderio griego da san Epifanio de Chipre*.

Noachian list with hundreds of known peoples. The question had first been raised by Greek-speaking Jews, including Flavius Josephus, and the authors of the targums (translation or paraphrase of the Bible in Aramaic), and their solution was to equate some biblical names to known ethnonyms; these comments were added in the form of *midrashim*. Christians adopted this approach in a far more systematic manner: the nations of the world, descendants of Shem, Ham and Japheth were to be the recipients of the Gospel, and they had to be connected to Noah. The *Diamerismos* attributed to Hippolytus of Rome (*c.* 235) was the main model on how to think on the subject, integrating data from Greek regional geography with new concepts such as 'derived peoples.' He dominated the field throughout late antiquity in Greek (the *Paschal Chronicle* *c.* 630), Latin and Syriac, and his influence endured even if there is also a tradition inherited from Josephus (Pseudo-Eustathius, fifth century).[26]

We find this kind of synthesis elsewhere. Nemesius of Emesa, a physician converted to Christianity, wrote in about 400 CE a treatise *On Human nature* that combined biblical contributions (the creation of man by God) and Graeco-Roman tradition (on the relationship between the soul and the body).[27] From a historical perspective, the certainty that the biblical story was truer than others (asserted by Theophilus of Antioch, *Apology to Autolycos* 2.30 and 3.26, and Origen, *Peri archon* 3.5.3) was coupled with the possibility of integrating past nations in biblical chronology. This was done over four centuries by the universal Christian chroniclers: Julius Africanus, Eusebius of Caesarea, Panodorus and Annianus of Alexandria, Hesychius of Miletus and John Malalas, the *Paschal Chronicle*. Hippolytus of Rome alone favoured a Biblical-Christian chronology.[28]

Some cases were more complex because of the inherent tension between 'inner' and 'outer' knowledge.[29] Medicine, for instance, which is discussed in a section of this book, saw the rise of advocates of divine healing based on prayers and miracles opposed to those who relied on knowledge of Graeco-Roman origin. Some geographical issues were also debated.[30] The centrality of Jerusalem, at least symbolically, according to the Bible, was compatible with world maps inherited from Eratosthenes and Strabo, but not with that of Ptolemy, however, which was not disseminated widely before 550 CE. After 300 CE, two different locations were given to the earthly paradise in the East: Greek Christians placed it in Asia, the Syriac tradition and Constantine of Antioch

26 Inglebert, *Interpretatio Christiana*, p. 109–192.

27 Beatrice, *L'union de l'âme et du corps*.

28 Inglebert, *Le Monde l'Histoire*, p. 357–386.

29 Filoramo, *La vittoria di Cristo su Asclepio*.

30 Novembri, *I Cristiani e la geografia*.

(Cosmas Indicopleustes) in an eastern ultra-oceanic continent. The fact that all the oceans shared the same waters was consistent with the maps of Eratosthenes and Strabo, as well as with some biblical claims; but around 550, John Philoponus, relying on the geography of Claudius Ptolemy, raised some doubts, which led him to be accused of heresy by Constantine of Antioch. The issue of the inhabitants of the antipodes arose from those who believed in a spherical world because scholars thought the ocean could not be crossed, which would prevent faraway inhabitants from being concerned by the gospel of Christ; thus it was generally inferred that the antipodes were uninhabited.

But the most important debate was on cosmography, with three opposing views: between partisans and opponents of *paideia* and mainly of philosophy; between Graeco-Roman knowledge and Christian knowledge; between the supporters of literal exegesis and those of allegorical exegesis. These three oppositions were not combined originally, but they did after 350 and culminated in Alexandria around 550 in the debate between Constantine of Antioch and John Philoponus. As this debate on cosmography witnessed the clearest divide between the proponents of 'inner knowledge' and those of the 'outer knowledge,' we will analyse it in more detail. It will help us clarify how the paradigm of 'certainty' was established.

## 6 The Case of Cosmographic Models

In Mediterranean antiquity, there were two descriptive models of the world. The archaic cosmos was found in Mesopotamia, in Egypt, in the Bible (including the New Testament) and in Homer where the earth was flat, covered by an arching sky. There were many variants within this model, regarding the shape of the flat earth (round in Mesopotamia and for the Greeks, square for the Hebrews), or the number of skies (the Hebrews believed there was an ultimate sky-ceiling between the earth and the sky, and their tradition mentions two to ten levels), the movement of the stars (horizontal in Mesopotamia and for the Jews, oblique for the Egyptians and the Greeks) and the reason for nocturnal obscurity (the sun returning below ground to navigate Egypt's underground waters, passing behind the high mountains located in the North for the Babylonians and the archaic Greeks or moving behind the celestial canopy for the Jews). A Mesopotamian and biblical original view was the existence of higher waters since the creation of the world, which came of use during the Flood; this was why the Jews thought there were one or more intermediate heavens,

to contain the meteorological reserves.[31] The other model was that of a stable spherical earth at the centre of a moving spherical cosmos (the other variants of a moving earth at the centre of the cosmos or a heliocentric cosmos were marginal). It was a Greek model, which first appeared in the fifth century BCE and which prevailed among most Greek and Latin literati (except epicureans).[32]

The way eclipses were calculated was based on the same series of Babylonian astronomical observations in both systems, since they were used by Hipparchus around 150 BCE. Admittedly, the important variations in the duration of days according to latitude raised problems in the archaic model, but even testimonies in their favour, like Pytheas' travels, were deemed suspect and could be, as was often the case in geography, ignored. Similarly, the precession of the equinoxes (linked to the oscillation of the Earth on its axis) only made sense with a spherical model since Hipparchus explained it by the friction linked to a ninth sphere outside the fixed sphere, but the problem was only known to a few astronomers. This had three important consequences. Greek astronomers themselves admitted that their geometric models, based on the two (false) hypotheses of a central earth with circular orbits, were only there to save phenomenal appearances and could not account perfectly for the apparent downshift loops of the planets. Their knowledge was therefore very likely but not demonstrated. Then, the accuracy of observations and the possibility of predicting eclipses, a Babylonian arithmetic heritage, took on a new meaning when they were associated with the spherical geometric model, which went beyond the observation of eclipse phenomena to give them a causal explanation. However, causal explanation was a mark of philosophical knowledge.

This also reinforced the claims of mathematical astrology applied either to people (according to the horoscope linked to their date of birth) or to regions (according to the stars associated with them, which was supported by Claudius Ptolemy). Finally, since the calculations of Greek astronomers were known only to a small number of scholars, the dissemination of the two models was popularised mainly via schools. Knowledge of the spherical model was only available in Greek-type schools where *paideia* was taught.

However, in the Middle East, these schools were only found in cities and they were only accessible to the Hellenised elites. Moreover, in antiquity there were no courses on specific disciplines. Very little historical, geographical, and

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31 Neugebauer, *A history of ancient mathematical astronomy*; Walker, *Astronomy before the telescope.*

32 Duhem, *Le système du monde*; Samburski, *The physical world of the Greeks*; Lerner, *Le monde des sphères*.

astronomical lore was developed and only in connection with commentaries of literary works and, first in line, Homer. In the schools taught by a grammarian (for local elites) and those by a rhetorician (for the upper elites), most of the knowledge on astronomy came from the poem *Phaenomena* by Aratos or works by Plato or Aristotle which referred to a spherical model as it was conceived in the fourth and third centuries BCE, before Hipparchus' additions. As for those who did not attend schools where *paideia* was taught, the old model was one of spontaneous evidence and ancestral tradition, especially in Aramaic-speaking areas. Philo, a Jewish scholar trained in Alexandria, referred spontaneously to the spherical model (*De Cherubim*, 21–22), while the Talmudic rabbis of Palestine and Babylonia assumed the existence of the old model. And to bypass the biblical text, which clearly referred to this model, Philo adopted an allegorical reading of the passages in question, to ensure they would be compatible with Greek knowledge.

One of the original features of ancient Christianity was that these cultural and sociological aspects were plagued by exegetical issues. But most of the time, Christian writers only mentioned cosmographic issues in passing, as these points were of little interest to them in comparison to the omnipotence of the divine creator, the rejection of eternal matter or that of stars seen as autonomous animated beings. But, from the first to the seventh centuries, cosmographic views or similar arguments may have had very different meanings depending on the time and context of the debates.[33] The analysis of the relationship between the two cosmographic models highlights the fact that for the supporters of the archaic model, the difference between the two conceptions of the world was an opposition between a false, pagan knowledge and a true Christian knowledge. Yet, for Christian followers of *paideia*, 'outer' knowledge could be defined as secular and neutral, and considered true.

During the first two centuries, the cosmographic differences found in Christian texts were mainly due to cultural and sociological reasons, not religious or theological ones. Christians took up the various positions of Hellenistic Jews, the archaic model in Palestine and the spherical model in Rome, depending on the presence or absence of Greek schools. The situation was the same in the second century where three cosmographic traditions coexisted among Greek-speaking Christians.

On the one hand, Christians preserved the archaic cultural conceptions of the Semitic regions (Palestine, Syria, Mesopotamia), which were common in these regions (*Questions of Barthelemy*, the *Apocalypse of Paul*). Other Christians adopted the spherical model taught by Greek schools, like Athenagoras

33 Inglebert, *Interpretatio Christiana*, pp. 51–62.

and Clement of Alexandria, both Athenians. Finally, some Gnostic Christians attempted, based on the spherical model, to produce speculative syntheses, like Basilides, who imagined 365 heavens. But with the exception of the latter, these cosmographic differences are explained by local cultural traditions, not religious choices. The archaic model is present in Greek around 180 with Theophilus of Antioch or in Syriac in 340 with Aphraate and Ephrem of Nisibis, all close to contemporary Jewish traditions from Syria-Mesopotamia. Conversely, Christian scholars writing in Greek from 180 to 330 (Athenagoras of Athens, Clement of Alexandria, Julius Africanus, Hippolytus of Rome, Origen of Alexandria, Anatole of Laodicea, Method of Olympus, Eusebius of Caesarea in Palestine) or in Syriac (Bardesan of Edessa, *c.* 200) spontaneously alluded to the spherical model because they had been taught in *paideia* schools. Thus, from about 150 to 340, whether in Greek or in Aramaic (Syriac), the coexistence of the two models does not seem to reflect anything other than the culture of the authors and was not yet a subject of theological debate between Christians. However, Theophilus of Antioch rejected the spherical model as a Gentile mistake (*To Autolycos* 2.8 and 3.2).

The first treatises *On the Hexameron* produced after 200 have not been preserved, but in other texts there is no focussed cosmographic discussion before 340. It is likely that the claim that the archaic model alone was in line with the literal reading of the Bible was a reaction to Origen's allegorical exegesis. In any case, after 340, the choice of the archaic cosmographic model became more and more a conscious choice, discussed and argued, at least in Syria. Eusebius of Emesa asserted that the stars were in movement and not fixed to the firmament. Basing his arguments on the Bible and Homer, Acace, bishop of Caesarea in Palestine, rejected the spherical model. It was around 350, then, that scholars became aware of the exegetical problems raised by the spherical model. But it was only indirectly a polemic against pagans (unlike Theophilus of Antioch), since Eusebius of Emesa was not afraid to propose demonstrations based on Homer's archaic conceptions.

At the end of the fourth century the archaic model of the cosmos was used by exegetic specialists from Antioch. One might surmise that the tensions between Graeco-Roman culture and pagan Hellenism during Julian's reign (360–363) caused some Christians to harden their position vis-à-vis Greek knowledge defined as 'Hellenic.' In his treatise *On Fate*, Diodorus of Tarsus defended the archaic model to counter astrological fatalism, which was based on the spherical model among Greeks. In certain homilies on *Genesis* pronounced around 400, Severian of Gabala recuses the spherical model as that of the tenants of 'outer' knowledge, the 'Hellenes,' 'useless and unreasonable gossips' (*PG* 56, 452). The preserved fragments of Theodore of Mopsuestia are very

clear regarding his contempt for pagan knowledge, and his opposition to the autonomous movement of the stars made him say that they were moved by the angels, a theory of Jewish origin.

The archaic model is re-asserted by John Chrysostom (*Homilies on the Epistle to the Hebrews* 15.1 and *Homily on the incomprehensibility of God*) and by Theodoret of Cyrus (*Questions on Genesis* 11), and then by others in Armenia (Eznik Kolb, Elisha Vardapet). This entrenchment of cosmography in biblical exegesis and its connection with Christian dogma could only widen the chasm with the partisans of the Graeco-Roman tradition. In the same period, the spherical model was defended by Christian followers of *paideia*: it is found in the fourth century among Cappadocians (Basil of Caesarea, Gregory of Nyssa, Gregory of Nazianzus) and Egyptians (Athanasius of Alexandria, Didymus the Blind).

The context of the debate changed in the fifth century for two reasons. First, Theodore of Mopsuestia was the first to include two theological elements, not just exegetical ones, in the cosmological debate. His literal exegesis led him to suppose that the tabernacle of the tables of the covenant as described in the Pentateuch (supposedly written by Moses) was a model of the cosmos (of the archaic type). The consequence is that the flat earth was neither square nor round, but rectangular, and that the arch of heaven was barrel vaulted. In addition, his theology of the two catastases, the two successive human conditions, on earth and after the resurrection, led him (or his successors) to think that the kingdom of heaven was situated between the flat firmament (*stereoma*) and the vaulted sky (*ouranos*) and that it would only be accessible after the Last Judgment—except for Christ. Thus, the debate on cosmography took on a soteriological dimension. Proponents of the archaic anti-nestorian model did not accept these ideas: Theodoret of Cyrus (*Questions on Genesis*, *c.* 430), Jacob of Sarug (*Homily on the Hexameron*, *c.* 510), Pseudo-Cesarius (*Erotapokriseis*, *c.* 550), and the author of the *Paschal Chronicle* (*c.* 630) rejected the theory of the two catastases. However, Theodore of Mopsuestia, translated into Syriac, became the theological reference of the Persian Church in the fifth century and his ideas are even found in the works of Narsai (around 500).

The last Greek stage of this debate took place between Constantine of Antioch (known as Cosmas Indicopleustes in the handwritten tradition) and John Philoponus around 547–550 in Alexandria. It was cosmographic, theological and exegetical. Constantine of Antioch was a Syrian merchant living in Alexandria, where he met, around 525, Patrikios (Mar Abba), who later became head of the Church of Nestorian Persia. He wrote 'against those who pretend to be Christians, but believe and profess, like tenants of outer knowledge, that the sky is spherical,' firmly opposing the Biblical Antiochian truth to what he

considered to be miaphysite heresy and a pagan error. He systematized the link between the archaic cosmographic model (*Christian topography* 3.56: 'Moses is a divine cosmographer') and the theory of the double catastasis (of the two human conditions) of Theodore of Mopsuestia. The world was longer than it was broad, because of the model of Moses' tabernacle conceived as a model of the cosmos. This was confirmed by Graeco-Roman geography according to which the oikoumene was more stretched in longitude than in latitude. Constantine of Antioch then drew the consequences of his cosmographic model in a methodical way,[34] asserting that the stars were moved by angels and that night was due to the passage of the sun behind the mountains of the west and the north, an ancient archaic Greek conception revived by Severian of Gabala.

John Philoponus, a Christian miaphysite, disciple of the neoplatonic philosopher Ammonios and himself astronomer (he was probably the first to write a *treatise on the astrolabe*) fought on two fronts. He relied on Claudius Ptolemy in astronomy and geography to discuss point by point the ideas of Constantine of Antioch in his *On the Creation of the World*. He claimed a perfect concordance[35] between the reading of Genesis and the spherical conception of Greek astronomers in his *Commentaries on the Cosmography of Moses*. Against pagan scholars, who still endured in 550 in Alexandria, like Olympiodorus, he rejected the eternity of the spherical sky, which, according to him and Basil of Caesarea before him, was made of air and water and not of ether, which caused the necessary instability of the mixture. He also rejected the automotive trajectory of the stars which were not alive, nor were they pushed by angels as claimed by the Jews and Cosmas; they had received from God a driving force from an original push which was later understood as the theory of the *impetus*.

Because of the official condemnation of Theodore of Mopsuestia at the Council of Constantinople II (553), the spherical model was favoured later on throughout the Roman Empire. After 550 and in the following centuries, the archaic model was only supported in the Syro-Oriental Persian Church, where it was still defended by Ishodad of Merv in the ninth century. In contrast, the Syro-Western miaphysites (Jacobites) adopted the spherical model from 530 onwards after Sergius of Reshaina, who was the disciple of John Philoponus in Alexandria. Greek knowledge was translated into Syriac and disseminated in Syria in the seventh century by Severus Sebokht, Jacob of Edessa and George of the Arab tribes. The Syro-Westerners then circulated this knowledge among Muslim Arabs after 800.

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34 Wolska, *La Topographie chrétienne de Cosmas Indicopleustès*.

35 Scholten, *Antike Naturphilosophie und christliche Kosmologie*.

After 610, at the behest of Heraclius, Alexandria's knowledge was brought to Constantinople by Stephen of Athens, a Christian philosopher who had taught in Alexandria. He was a universal philosopher in the line of John Philoponus. Defender of the spherical model, he was not only an astronomer, but also an astrologer, a supporter of the star-sign theory of Philo and Origen, who rejected the theory of the celestial causes of fatalistic pagan astrologers,[36] condemned by Christians. His revival of Graeco-Roman knowledge and his need for synthesis in the service of knowledge on divine creation were transmitted to Tychikos of Trebizond (and through him to Ananias of Shirak who brought them to Armenia around 650), but also to Theodore of Tarsus who became Archbishop of Canterbury in 668. Towards 630, in Constantinople, the *Paschal Chronicle* still defended the archaic model, claiming the spherical cosmos was eternal and conflicting with the coming of the Kingdom of Heaven. But at the same time, George of Pisidia, in his *Hexameron* defended the sphericity and mobility of the sky, which was not eternal, in the tradition of Philoponus. Thereafter his conception prevailed.

## 7 Typology of the Debates

The great Christian debates between 200 and 600 focussed on 'outer' knowledge, in history, ethnography, anthropology, medicine, geography and cosmography, but several aspects between 'inner' and 'outer' knowledge must be distinguished.

The debates that opposed pagans and Christians were of two types. First, there were certain aspects that were evident for the pagans like matter being eternal but rejected by Christian faith on the basis of their belief in the Creation of the world. Each party knew what they wanted to demonstrate and used every available element in their argument. The same was true of other religious questions, such as the incarnation or the resurrection; Graeco-Roman knowledge was used or rejected by both sides, used for apologetic purposes by Christians, from Justin to Theodoret of Cyrus in Greek. The judgment on 'outer' knowledge was mainly rhetorical at the time and tactical. There were other equally polemical topics, but not directly related to Christian religious dogma: e.g. theurgy, magic or astrological practices that Christians generally considered demonic, exception made for some aspects of astrology.

Another type of debate between pagans and Christians, however, focussed on Christian knowledge that was not related to dogma, but to the Scriptures:

36 Magdalino, *L'orthodoxie des astrologues.*

the mention of the Upper Waters in Genesis, if they were not evacuated by an allegorical interpretation, contradicted the theory of the natural place of bodies according to which water could not exist above air. To counter their critics, Christians had to assume that this upper water was present in the form of vapour, which was lighter than air (Basil of Caesarea) or ice, since it was beyond Saturn, a cold planet (Ambrosius of Milan).[37]

Other debates on knowledge were secondary from the point of view of the relationship between Christians and pagans and led to syntheses, in anthropology (on the nature of the humans), in ethnography and history. From the point of view of Christians, there existed in these areas potential complementarities between biblical and secular knowledge, where the latter completed the first. This point of view was hardly disputed by the pagans, except by a few philosophers. The Christians discussed the links between Noachian ancestors and contemporary peoples (Hippolytus and Epiphanius), but this did not concern pagans, who were not interested in the ethnography of the past. In history, debates against pagans first focussed on the question of the anteriority and primacy of biblical history; despite some attempts by Neo-Platonists to defend the long chronologies of the Babylonians or Egyptians (but their arguments were unconvincing according to the criteria of the Greaco-Roman tradition), biblical dating based on the Scriptures prevailed.

The impact of Porphyry's critics on the dating of *Daniel* or the contradictions between the Gospels was limited by the destruction of his works and a flood of various refutations. The debates on the sack of Rome in 410 with Augustine's *The City of God against the pagans* or Oroses' *Histories against the pagans* were brief Latin episodes, because Zosimus seems quite isolated after that.

Finally, the discussions on Constantine, Julian and Theodosius were episodical. In fact, Christians included Graeco-Roman political and cultural history into their chronicles as early as the third century, to produce syntheses. They could discuss among other subjects the synchronisms between the Bible and the secular chronological tradition (Eusebius of Caesarea against Julius Africanus), or the inclusion of antediluvian chronology (Panodoros against Eusebius), but these were technical, not theological discussions. As for the distinction between classicizing history (political and military) and ecclesiastical history from 300 to 630 in the East, it did not necessarily refer to different social or religious backgrounds, even if the former was the work of laymen alone. Then, the historical traditions of classicizing history, ecclesiastical history and the chronicle came to a halt after 630, because of the impossibility to justify the

37 Inglebert, *Interpretatio Christiana*, pp. 210–16.

victory of the Muslim Arabs, considered to be barbarian heretics, over the Christian Roman Empire.

These first two types of debate were in fact solved by the Christianization of the ancient world. Pagan arguments were forgotten, or, if they were preserved, lost their radical challenging potency. They were allowed to survive as theoretical problems, secondary to the questions of salvation. This explains their marginal presence in the texts in comparison to theological debates.

Two other debates only occurred between Christians, which led them to ask different questions regarding the relationship between 'inner' and 'outer' knowledge.

The first concerned medicine and went through two phases. Originally, the debate focussed on the preference to be given to human medicine or divine medicine. This was a legacy of the Hellenistic era where folk medicine, Hippocratic scholarly medicine and temple medicine were separate entities, even though the third was quite close to the second, despite certain practices like incubation. If the rejection of false healer demons and the cry for help to Christ as a physician were constant from the very beginning of Christianity, the situation transformed sociologically in the fourth century. Temple medicine disappeared officially with the end of the Asklepeion and the destruction of shrines linked to healing waters.[38] The Christian sectarian or ascetic discourse, which put its hope in God alone, and in its agents, the saints, dead or alive, was then confronted to popular medicine, now considered demonic because of its connection to the old pagan forces of nature, or scholarly medicine, sometimes considered to be a vain pursuit, at least in the stories of the miracles of the saints. But prayer or intercession of the relics of martyrs and miracle workers did not cure everyone. Beyond the theological debates of the sixth and seventh centuries concerning who produced miracles, God, angels, the posthumous *virtus* of the saint in his relics[39]—the Nestorians of the Eastern Church rejecting this last hypothesis—, from late antiquity onwards, these different medical forms coexisted, with varying success according to sociological circles and financial means.

Three healing systems endured amid aporetic debates: folk remedies rejected by physicians, clerics and monks; ecclesiastical miracles under the control of bishops and ascetics; galenic medicine reserved for the urban rich, which could also be presented as knowledge on the divine creation.

The second debate concerned cosmography, and occasionally geography. From about 200 to about 340, questions about exegetical methods and their

38 Covolo/Sfameni Gasparo, *Cristo e Asclepio*.

39 Dal Santo, *Debating the Saint's Cult in the Age of Gregory the Great*.

relationship to philosophy divided Christians for both cultural and religious reasons and were able to integrate discussions with pagans. The main debates on cosmography between Christian partisans and opponents of the archaic and spherical models occurred between the years 340–550. After 550, the condemnation of the Three Chapters and the end of Antiochean exegesis favoured the spherical model that dominated Byzantium.

## 8 Conclusion

In late antiquity, Christians did not reject 'science' in the modern sense—since it did not exist—but Graeco-Roman knowledge that was often impossible to demonstrate. In the fourth century CE, to explain the genesis of the world, one had to choose between the Christian Bible or neo-Platonic *Timaeus*, that is to say between two systems of thought which, ultimately, were based on beliefs and arguments, but never on decisive evidence. Debates between 'inner' and 'outer' knowledge occurred more often between Christians than between Christians and pagans, for chronological reasons (there were less and less pagans) but also ideological (it was mainly an exegetical or theological debate); the pagans debated more on philosophical themes than on the nature of knowledge. Among the fields concerned by the Christian debate on biblical and 'outer' knowledge, that on cosmography was the most conflictual, because it was at the intersection of exegetical, philosophical and theological debates; because of this, it is the most important in terms of chronology.

In late antiquity, one can distinguish three Christian approaches to 'outer' knowledge and 'inner' knowledge. The first condemned some forms of knowledge of the world as heretic based on a literal understanding of the Scriptures and wanted to create a biblical or ecclesiastical Christian knowledge, a *scientia christiana*. It hardened the debate between 'outer' knowledge and 'inner' knowledge; its main supporters were: in the years 360–390, Epiphanius of Salamis and Philastrius of Brescia; then Philip of Side (*c.* 420–430) and his *Christian History*; and finally Constantine of Antioch (*c.* 547–549) in his *Christian Topography*. Then, the rejection of 'outer' knowledge, considered to be 'pagan,' a legacy of a certain Jewish and Christian cultural traditions, persisted among the Syro-Orientals ('Nestorians') of Persia, and sometimes also among some Byzantine monks.

The second attitude was the subordination of 'outer' knowledge to 'inner knowledge,' advocated by Clement of Alexandria and Basil of Caesarea and which later became the norm. It could be accompanied, depending on the field, by syntheses (ethnography, history, anthropology), by a parallel coexistent field

(medicine) or separate forms of erudition (Eusebius of Caesarea developed scholarly knowledge of the Bible in the *Onomasticon* [*c.* 295] or of Christianity in his *Ecclesiastical History* [*c.* 310]; Augustine of Hippo would later encourage this kind of work in his *De doctrina christiana*). The use of pagan knowledge in the service of biblical truth characterized the world of Chalcedonian orthodoxy and imposed itself both in Constantinople in the seventh century as in the Latin West.

The third attitude was that of a concord struck between 'outer' and 'inner' knowledge advocated by John Philoponus. The acceptance and revival of 'outer' knowledge, an Alexandrian legacy of the sixth century which insisted on using Aristotle to distinguish itself from Athenian Neoplatonists and Heraclius' Constantinople, is found among Armenians and Syrian-Western (Miaphysites) and was later disseminated by the Arab-Muslim tradition.

As Christian scholars were the majority after 400, and they hardly entered into debates with pagans after 430 (except in the case of Philoponus), understanding the debates that occurred between Christians is essential to understand later forms of knowledge in Byzantium. Just as Greek astronomers built geometric models to 'save the phaenomena,' so did the Christians, after the Jews, elaborate exegetical models to reconcile biblical data and common observations. The problem was more one of meaning and rhetorical argument than that of seeking the truth which was in those days unprovable, as there was no 'science' in the current sense of the term.

The political contexts (Julian's actions in 362, Justinian's regarding the authors of the Three Chapters in 553, Heraclius' regarding Stephen of Athens in 619) and cultural contexts (the presence or the disappearance of *paideia* schools), the exegetical traditions (the literal and historicizing Antiochian reading of the Bible) or theological traditions (the theory of the double catastasis of Theodore of Mopsuestia), the sociology of scholars (laymen, clerics or monks), the evolution of the appreciation of knowledge (privileging the study of Aristotle versus Plato in Alexandria at the end of the fifth century, the acceptance of Greek knowledge by Syrian-Western monks after 520), must be taken into account to properly assess how 'outer' knowledge was valued by Christians in late antiquity, and its later integration into Byzantine culture. The subordination of secular knowledge to theology and the acceptance of Graeco-Roman knowledge as part of an exegesis of Genesis by Basil of Caesarea, later revived by Philoponus, played a decisive role in the subsequent survival of Greek knowledge in Byzantium, justifying their presence alongside Christian truths.

CHAPTER 2

# Science Teaching and Learning Methods in Byzantium

*Inmaculada Pérez Martín and Divna Manolova*

## 1 Introduction: Questions of (Dis)continuity and the 'Why Not' Question

Modern science and its focus on experimentation have shaped our contemporary idea of what science essentially is and what we should expect from it.[1] It is thus important to discuss the major methodological problem we are faced with when exploring any aspect of medieval 'scientific' thought, namely, whether referring to a Byzantine science is justified and what an adequate and methodologically sound working definition of science would be in the context of the premodern and, by extension, of the Byzantine world.[2]

The scholarly debate as to whether medieval (that is, western medieval) natural philosophy is scientific, in the modern sense, has already taken place. In the 1970s, medievalists chose to employ or reject Kuhn's model of shifting scientific paradigms[3] in their attempts to resolve the problem of (dis)continuity between medieval and modern western European scientific thought. Famously, in 1973 during the First International Colloquium on Philosophy, Science, and Theology in the Middle Ages, Murdoch argued for the "unitary character of late medieval learning" and that fourteenth-century science was in fact philosophy.[4] In 1997, Sylla and McVaugh advocated, much in the same spirit, understanding "medieval science cum philosophy in its own terms, as an

1 Cunningham, "The Identity of Natural Philosophy," p. 261: "Now when, as historians of science, we use the terms 'science' and 'scientific' about the medieval period… [w]hat we mean is that the practice or text we are discussing reminds us of (modern) science—reminds us of what we today know as science in our own world—and looks to us simply like an early version of it."

2 Most recently on the Aristotelian conception of science and its development in Byzantium, see O'Meara, "Conception of science in Byzantium."

3 Kuhn, *The Structure of Scientific Revolutions*.

4 Murdoch, "From Social into Intellectual Factors."

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approach to understanding the world that may or may not have similarities to modern alternative approaches."[5]

Lindberg in his seminal 1992 survey *The Beginnings of Western Science*, however, argued in defense of employing Kuhn's model:

> I *do* believe that medieval natural philosophers made many important and enduring contributions to the Western scientific tradition—contributions that helped to shape this tradition and serve, in part, to explain it. But medieval natural philosophers did not anticipate the basic elements of early modern science; and the latter was far more than an extension, adaptation, and fuller articulation of the medieval worldview.[6]

It ought to be noted that in the second and revised edition of *The Beginnings of Western Science*, Lindberg modified and nuanced his position. After a short summary of the history of the 'continuity question,'[7] Lindberg examined aspects of both continuity and discontinuity between medieval and modern science and identified the shift from an Aristotelian and Platonic metaphysics to Epicurean atomism and, subsequently, to the metaphysics of the so-called 'mechanical philosophy' of the sixteenth and the seventeenth centuries, as "a radical conceptual shift, which altered the foundations of natural philosophy."[8] Nevertheless, Lindberg also pointed out that "*revolutionary* achievements in many disciplines were built *on medieval foundations* and *out of resources* provided by the classical tradition," thus emphasizing the role of continuity in the progress of theoretical science.[9]

The culmination of the continuity debate, however, took place in a series of published exchanges between Cunningham and Grant.[10] While Grant saw the high Middle Ages in the Latin west as an "Age of Reason" that foreshadowed the developments in thinking about the natural world which took place in the seventeenth century, Cunningham argued for discontinuity between medieval natural philosophy and (modern) science and for them being essentially

5 Sylla/McVaugh, "Introduction," p. xv.

6 Lindberg, *The Beginnings of Western Science* (1st ed.), p. 360. This paragraph was excluded from the second and revised edition of the work.

7 Lindberg, *The Beginnings of Western Science* (2nd ed.), pp. 357–59.

8 Lindberg, *The Beginnings of Western Science* (2nd ed.), p. 365.

9 Lindberg, *The Beginnings of Western Science* (2nd ed.), p. 366.

10 Cunningham, "How the *Principia* Got Its Name"; French/Cunningham, *Before Science*; Grant, "God and Natural Philosophy"; Grant, "God, Science, and Natural Philosophy"; Cunningham, "The Identity of Natural Philosophy."

different, natural philosophy being always about God and His creation. Framing his criticism, Cunningham voiced a methodological concern that is equally relevant to the 'scientific' thought produced in the Greek medieval east:

> The meanings we attribute to the term 'science' in our researches and writings as historians of science are crucial, yet are usually uninspected and unspecified by us. This is a potential source of confusion and mistaken identities. We use the term 'science' in many senses. Sometimes we mean the activity of making science, sometimes we mean the product of scientific research, sometimes we mean an attitude of mind, sometimes we mean an external judgement made on the status of a statement or activity, sometimes we mean more than one of these at once. It is a very slippery term. We rarely specify which meaning we intend at a given time, relying on our readers or listeners to recognise which one we mean.[11]

What is important for our discussion, however, is not to solve the continuity debate, but to emphasise, first, that an equivalent discussion has not taken place so far in the field of Byzantine studies and second, that when medievalists have problematised the 'scientific' status of natural philosophy in Europe, they have taken Byzantium into account only insofar as it acted as a repository of ancient knowledge that was to be transmitted to the Latin west through translation. Thus, the case for revising the narrative concerning the role played by Byzantine 'scientific' thought in the building of the intellectual heritage of medieval Europe remains to be made.

The type of methodological concern that students of Byzantine science and philosophy have raised, though perhaps rather accidentally, could be compared to the so-called 'why not' question historians of Chinese science have been discussing for at least four decades, namely "Why did the 'scientific revolution' not take place in China?" and "Why did modern science not develop independently in China?"[12] Especially in the fields of intellectual history, history of philosophy, and history of science, a similar question could be formulated about Byzantium in comparison with its Latin medieval cultural counterpart, namely "Why is that Greek and Latin medieval thought developed differently (in terms of 1) the scholarly strategies of engagement with the pre-existing shared ancient and late antique tradition; 2) the institutionalization of philosophical and scientific learning; 3) the development and use of

11 Cunningham, "The Identity of Natural Philosophy," p. 260.
12 See for instance Kim, "Natural Knowledge in a Traditional Culture."

scientific literary genres; and 4) the social and political importance and implementation of philosophical and scientific learning)?".

Posing the 'why not' question, however, is not necessarily productive as it involves endorsing an assumption that Yung Sik Kim dubbed "the assumption of a single developmental pattern of universal science."[13] Moreover, a juxtaposition with the "Latin West" as if the latter were a single homogenous entity can be equally misleading. An alternative approach was proposed recently by Signes Codoñer who advocated examining the scientific knowledge the Byzantines were interested in producing on its own terms.[14] Drawing upon the views expressed by Stuloff,[15] Signes Codoñer argued for a "retrospective" (as opposed to progressive) idea of the role of the sciences. That is, the role of science was to reconstruct and harmonize the existing scientific legacy without the need to innovate and open up unexplored scientific areas or methods. Signes Codoñer pointed out further that while the Byzantines produced original knowledge in areas such as what is known today as pure mathematics, this was only a by-product of their efforts to harmonize a tradition rather than a deliberate attempt at innovation. Given the large Greek scientific tradition they inherited and the pervasively Christian societal framework the Byzantine scholars (according to Signes Codoñer [*pace* Stuloff]) simply did not view the need for science to outgrow itself, as the knowledge it already offered was sufficient to explain the creation.

Importantly, both scholars have raised an objection to the mainstream scholarly view that traditionally tends to commit two methodological fallacies. First, it applies to a premodern society the terms 'science' and 'scientific' employing the meaning they acquired after the Scientific Revolution. Consequently, it seeks to find precursors or even equivalents of sixteenth- and seventeenth-century scientific developments assuming in this very search that there is a radical rupture dividing the two.[16] Second, it tends to juxtapose the Byzantine scientific heritage with the contemporary Latin medieval, Jewish medieval, and Islamic scientific practices. The resulting comparison is inevitably a negative and even a derogative one: while Byzantium played an invaluable role in the preservation and transmission of ancient Greek science, it hardly played any part in its development and it produced a fairly limited number of original scientific contributions. Discussing both the 'continuity'

13 Kim, "Natural Knowledge in a Traditional Culture," p. 86.
14 Signes Codoñer, "Ciencia y técnica en Bizancio," pp. 248–50.
15 Stuloff, "Mathematik in Byzanz."
16 On the questions of method and terminology when approaching the subject of 'Byzantine science,' see also chapter 1 in the present volume.

and the 'why not' questions with a reference to the Byzantine material serves the student of Byzantine science in at least two respects. First, it demonstrates the importance of understanding Byzantine scholarship in its own terms. This encourages us to examine Byzantine scientific texts as products of the related educational, societal, and cultural frameworks that provided the demand and the use cases for the knowledge produced within the field of the four μαθήματα, that is arithmetic, music, geometry, and astronomy. Second, it reveals the importance of the conceptual and programmatic framework of philosophy understood in a larger sense within which the sciences were nested. In other words, it is impossible to understand the teaching and learning of the sciences in Byzantium, as well as the related processes of organization (book production) and transmission (book circulation) of knowledge, if we do not consider the influence philosophy and rhetoric exerted on the sciences in terms of scope and purpose, method, discourse, and literary output.

The rationale Byzantine scholars most commonly employed in order to justify any educational activity stated that it is the noble obligation of humankind to pursue knowledge, not only as dictated by our rational nature but also so that we can equip ourselves with the epistemic tools necessary to understand the creation.[17] In his *Hortatory Letter Concerning Astronomy*,[18] for instance, Nikephoros Gregoras (*c.* 1294–*c.* 1360) noted that it would be a shame if "on the one hand, the heavens resonating around the entire earth describe God's glory, while on the other, we turn a deaf ear not paying attention to the things they say."[19] Earlier, George Pachymeres (1242–*c.* 1310) elaborated the relation between the pursuit of knowledge and the achievement of happiness in the introduction to his *Quadrivium*.[20] Similarly, already in the early seventh century, George of Pisidia wrote that it is humankind's obligation to study the creation.[21] It is, however, the *Hexaemeron* written by George of Pisidia that manifests an epistemological framework that will turn out to be the generally prevailing one

17 On this *locus communis*, see further examples and bibliography in Cacouros, "La philosophie et les sciences du *trivium* et du *Quadrivium*," p. 9, n. 22.

18 An autograph copy of Gregoras' *Hortatory Letter concerning Astronomy* is preserved on fol. 1r–v of Vatican, Biblioteca Apostolica Vaticana, gr. 1087. A revised version of the letter was subsequently included in Book VIII, 7 of Gregoras' *Historia Rhomaike* and has been edited together with the rest of the historiographical account by Schopen in 1829. The earlier and independently circulating variant of the letter was never included in any of the modern editions of Gregoras' letter-collection and thus remains unedited. For further discussion, see Manolova, "If It Looks Like a Letter."

19 Vat. gr. 1087, fol. 1v: "[…] οὐρανοὺς μὲν διηγεῖσθαι δόξαν θεοῦ περιηχοῦντας πᾶσαν γῆν, ἡμᾶς δὲ κωφεύειν οὐκ ἐπαΐοντας ἅττα φασὶν […]."

20 George Pachymeres, *Quadrivium*, Book 1, p. 5, lines 1–16 (ed. Tannery/Stéphanou).

21 George of Pisidia, *Hexaemeron*, lines 600–21 (ed. Tartaglia, pp. 346, 348).

in Byzantine theories concerning the acquisition of knowledge about the natural world and the relationship and interaction between humanity and nature. While also informed by Neoplatonic cosmology, the world Pisides sets up as available for us to know is fundamentally characterized by the fact that, within the Christian framework, the universe is ultimately a creation.[22] Thus, Pisides described the terrestrial and heavenly phenomena and the intellect's journey in acquiring knowledge about each of them. Pisides provides a progressive model, starting from the basic elements in order to reach higher science.

The present chapter is certainly not going to offer a definitive answer as to what science meant in the Byzantine context and which texts we should read today as scientific. As it shall become obvious when we use 'science' and 'scientific' throughout what follows we employ them as terms of convenience that encompass first and foremost the idea of systematic knowledge and related expertise. Second, relying on the stricter sense of the word in contemporary English, we use 'science' to refer, on the one hand, to the so-called ἡ μαθηματικὴ τετρακτύς or the tetrad of arithmetic, music, geometry, and astronomy, and on the other, to related cognitive fields such as geography, pharmacy, and medicine. What this chapter will do, however, is to trace the sociology and phenomenology[23] related to the process of transferring scientific knowledge in Byzantium from the ninth century, when intellectual life resumed after the radical change ushered in by the empire in the so-called 'dark centuries.'[24] In doing so, we have to tackle a number of difficulties, mostly resulting from the lack of evidence or the insufficient extent to which the existing evidence has been studied,[25] such as our limited knowledge of the practices of teaching and learning in and out of the classroom or our reservations as to the extent to which scientific books were actually read and applied to instructional purposes beyond the needs and personal interest of the copyists themselves. Ultimately, our aim is to survey the information available at present, to identify

22 Nodes, "Rhetoric and Cultural Synthesis," p. 277.

23 We use the designation "phenomenology of teaching/learning" to refer succinctly to the method of describing and classifying the totality of characteristic elements (*phaenomena*) constituting the everyday processes of knowledge transfer in Byzantium: where and when learning and teaching took place, who and what was involved, how teaching and learning were experienced by the participants, and so on.

24 This is the traditional name given to the seventh and eighth centuries, marked by the economic crisis provoked by the Slav invasions of the Balkans and the Arab conquest of the eastern Mediterranean.

25 In the detailed Karp/Schubring (eds.), *Handbook on the History of Mathematics Education*, Byzantium occupies just five lines on p. 144 in the chapter on Orthodox Europe by A. Karp. It merely mentions that mathematics were studied at the schools of Maximos Planudes (d. post 1305) and George Akropolites (d. 1282) through Euclid and Nicomachus.

and discuss the main trends and developments in science teaching and learning in Byzantium and finally, to point out the directions for future research that we believe are methodologically sound and most appropriate to the Byzantine material. After having discussed the conceptual framework of the sciences in relation to the general framework of Byzantine education (§ 2), we start by describing the educational context (§ 3). We examine Byzantine books in order to shed some light on the process of teaching and self-teaching (§ 4) and we try to recognize school texts from the general approaches through the single handbooks and introductory treatises or poems to the questions-and-answers collections, problems, or riddles (§ 5). Finally, we will try to understand the role of figures and diagrams (§ 6), and the different supplementary strategies implemented to teach scientific knowledge (§ 7).

## 2 The *Cursus Studiorum*

Our assumption that the sciences were taught in Byzantium is mostly based on circumstantial evidence. What we usually know is: 1) that certain individuals who possessed the necessary expertise produced commentaries, treatises, and textbooks of mathematics, harmonics, and astronomy; 2) that they were taught by other such individuals and that they were teaching themselves; 3) that knowledge of the *Quadrivium* was transferred through the restoration and production of books. Thus, based on both the prerequisites and the results of the educational process, we can certainly claim that such processes existed.[26] That, however, does not change the fact that we do not know much about the process itself. In other words, it is challenging for us to recreate the didactic situation in which scientific instruction occurred in a Byzantine school (public or private). One peculiar difficulty we encounter is defining the murky boundaries between teaching and self-teaching.[27] In other words, with regards to the available manuscript evidence, it is often difficult to assess whether a certain book was produced for the private learning purposes of its copyist or commissioner or whether it belonged to an educational environment with a higher level of institutionalization such as that given in a Byzantine school since both

26 See the reflections of Vitrac, "Quand? Comment?," p. 46, on the consubstantiality of learning (μανθάνω) and mathematics (μαθηματική).

27 An illuminating example is provided by John Katrarios' colophon in the MS Vatican, Biblioteca Apostolica Vaticana, gr. 175, fol. 158v. Referring to the material contained in the codex, namely Ptolemy's *Handy Tables* and Theon's *Small Commentary*, Katrarios points out that he studied the material and exercised on it without anyone else's assistance. English translation of the colophon is provided by Tihon, "Astronomy," p. 197.

processes existed in parallel. It is perhaps Michael Psellos (1017/8–1078?) who most frequently and most distinctly took pride in his accomplishments in teaching himself and others:

> I gathered knowledge gradually and by myself [...] I often conversed with books and searching for their doctrines, I discovered some of them myself through pure research and based on acknowledged principles; [...] I collected the subject-matter of geometry, being the first one to teach this science to my pupils; I analyzed the mathematical proportions in music and I corrected numerous points in the theory concerning the movement of the heavenly sphere.[28]

An additional complication arises when we assess the intended audience for the scientific literature we believe was produced for educational purposes. While a compendium of the mathematical sciences may fit our contemporary criteria for a secondary level of education, it is often difficult to assess in light of the surviving evidence whether any higher level of instruction was provided in the schools during a given period, even though we know of individual cases showing greater proficiency in the subject matter.[29] In sum, we know, for instance, who studied mathematics, based on their subsequent activity in producing mathematical texts. We know what they studied as they tell us in letters, monodies, historiography, and hagiography. We also know, based on the production of mathematical books and handbooks, where the interest of readers is being directed at any given epoch. We also know who taught mathematics, where and when. What we know the least about, however, concerns the details as to how mathematical knowledge was taught and learned.[30]

28 Αὐτίκα ἐμοὶ μὲν ἡ γνῶσις συνείλεκται [...] θαμά τε γὰρ ὁμιλῶ τοῖς βιβλίοις καὶ τὰ μὲν αὐτῶν ζητῶν ἐφευρίσκω, ἐξ ἀρχῶν ὁμολογουμένων συμπεραινόμενος, τὰ δέ, ὡς παρὰ ξυνιέντος μου, ὁ εἰδὼς λαμβάνων τὴν διδασκαλικὴν ἐπιστήμην ποιεῖτα μοι. ἐντεῦθεν καὶ φιλοσοφίας ἅττα ἐξέμαθον καὶ τὴν γλῶτταν ταῖς σοφιστικαῖς τέχναις ἐκάθηρα καὶ γεωμετρίαν τοῖς ἐφ' ἡμῖν συμπεπόρισμαι πρῶτος ἐπιβαλών, καὶ μουσικῆς λόγους ἐξεύρηκα καὶ τῶν περὶ τὴν σφαῖραν κινήσεων οὐκ ὀλίγα διωρθωσάμην καὶ τῶν ἡμετέρων λόγων τὴν ἐπιστήμην ἀκριβεστέραν ἐποιησάμην. Psellos, *Epistula ad Michaelem Cerularium*, § 22–24, ed. Criscuolo, transl. Agapitos, "Teachers, Pupils," p. 183. The last part of his *Encomium in matrem* speaks up for Psellos' immense erudition (transl. Kaldellis, pp. 99–108).

29 See Tihon, "Enseignement scientifique à Byzance," pp. 99–100. A possible exception is the scientific production of the Palaiologan period which is extremely abundant and well preserved. A comprehensive study of the late Byzantine manuscripts transmitting mathematics, astronomy, and harmonics has the potential of revealing more clearly the difference between secondary and higher education in the mathematical sciences.

30 Tihon, "Enseignement scientifique à Byzance," p. 89, voiced a similar concern already in 1988.

According to the *Hexaemeron* of George of Pisidia, the first stage in the examination of reality relies on sense perception. Its purpose is the collection of information concerning the natural world that would eventually lead to forming an understanding of the order of natural objects. In Tartaglia's words, the *Hexaemeron* is a "summa" of all that humankind is able to know.[31] Thus, the author demonstrated varieties of technical knowledge related to different parts of the creation, notably astronomy and medicine, but also geometry, meteorology, botany, zoology, and pharmacy. His use of technical vocabulary was noted in the eleventh century by Michael Psellos in his comparative essay *De Euripide et Georgio Piside judicium* (*To One Asking Who Wrote Verse Better, Euripides or Pisides*).

Pisides' *Hexaemeron* is not a *Quadrivium* textbook nor does it necessarily reveal its author's education.[32] Nevertheless, it testifies to the theoretical premise of Byzantine education, namely humankind's obligation to learn and understand the divinely created universe as well as the human condition. By extension, Pisides' *Hexaemeron* also reveals those disciplines that can assist humankind in its examination of the world, and thus, we learn of the importance of medicine (in order to understand humanity) or that of physics and astronomy (in order to explore the terrestrial and celestial phenomena).

A testimony from the ninth century provides us with a detailed and standardized image which translated the principles found in Pisides' *Hexaemeron* into a 'realistic' picture of the general curriculum and the place of the sciences within and in relation to philosophy. Patriarch Nikephoros I of Constantinople (d. 828) embarked on his educational journey with the intention of joining the imperial chancery. While the school where he pursued his studies is not specified in Ignatios the Deacon's *Life of the Patriarch*, details are provided of the curriculum he followed. Fisher has also suggested that the author of Nikephoros' *Vita* of Ignatios the Deacon (*c.* 770/80–after 845) might have followed the same educational path.[33] According to Ignatios, Nikephoros first studied the Scriptures and rhetoric, before proceeding to training in the disciplines of the *Quadrivium*. Basing himself on an Aristotelian conception of mathematics, Ignatios presents the 'scientific' curriculum first as divided between the study of

31 George of Pisidia, *Carmi*, ed. Tartaglia, p. 28.

32 Bianchi has argued, for instance, that Pisides' knowledge of Aristotelian and Ptolemaic cosmology and astronomy came from a textbook derived from the original scientific classics. See Bianchi, "Sulla cultura astronomica di Giorgio di Pisidia," p. 51. For a further discussion of Pisides' knowledge of astronomy, philosophy, and medicine as attested by his use of technical vocabulary, see Frendo, "The Significance of Technical Terms," pp. 45–55.

33 Fisher, "Life of the Patriarch Nikephoros I of Constantinople," p. 32.

moving (astronomy) and stationary (geometry) objects, on the one hand, and arithmetic and music (respectively, on absolute and relative quantity), on the other. Notably, Nikephoros' *Vita* emphasizes the subordinate role of the *Quadrivium* to philosophy, the latter described in detail by Ignatios following a list of topics derived from Aristotelian dialectic and physics.[34]

Perhaps the most celebrated testimonies recording the pursuit of an educational programme including the four mathematical sciences dating from the Komnenian period are those written by Michael Psellos in his *Chronographia* (6.36–46, ed. Reinsch) and by Anna Komnene (1083–1153) in the prologue to her *Alexiad* (Prol. 1.2, ed. Reinsch/Kambylis). Both narratives related the study of the *Quadrivium* to that of philosophy, whether they reflect on it or not. Anna Komnene mentions having studied the four μαθήματα after reading the works of Aristotle and Plato, while Psellos discusses mathematics as a gateway to the study of the principles of philosophy. In Psellos' account, the first encounter with mathematics follows the study of syllogistic that, in turn, leads to an expanded philosophical programme including Aristotle, Plato, Plotinus, Porphyry, Iamblichus, and Proclus. Before proceeding to metaphysics, however, Psellos returns to mathematics and this is where the narrative finally lists the four quadrivial sciences in the following order: from arithmetic and geometry to music and astronomy. Thus, in Psellos' account syllogistic precedes the *Quadrivium* whereas the higher philosophical studies follow it. The parallel educational autobiography Psellos detailed in his *Encomium for His Mother*, however, presents a reverse image as he details first his studies of rhetoric, physics, and the *Quadrivium* and only then, returns to syllogistic.

Nikephoros Blemmydes (1197–1272) described his education in Book 1 of the autobiographical *Curriculum vitae* (*A Partial Account of His Personal History*) written in 1264. Seven years of the study of medicine (both theoretical and practical) followed the study of grammar, rhetoric, and logic. Then, Blemmydes continued with the *Quadrivium*.[35] The study of astronomy is the one to which Blemmydes devotes the longest part of the narrative, carefully distinguishing it from astrology and prognostics. Blemmydes' *cursus studiorum* then returns to philosophy and syllogistics in particular, notably entirely omitting harmonics. What follows is physics, the study of which, however, Blemmydes was not able to complete.[36]

34 Ignatios the Deacon, *Vita Nicephori*, ed. de Boor, pp. 149–51.

35 *Autobiographia* 1.8–10 (English transl. Munitiz, pp. 46–48).

36 On Blemmydes' education and its stages, duration, and curriculum, see Cacouros, "La philosophie et les sciences du *trivium* et du *Quadrivium*," pp. 10–12.

Another late Byzantine 'autobiographical' text that offers a glimpse into the contents of the advanced educational curriculum is Theodore Metochites (1270–1332)' *Poem* 4, probably composed in the mid-1320s and addressed to his student Nikephoros Gregoras.[37] The first part of the poem discusses all the areas of knowledge Gregoras should continue to pursue in future, emphasizing their importance and specifying their proper order: first rhetoric, then philosophy, finally mathematics and astronomy. Gregoras had already completed his education in rhetoric under John XIII Glykys (d. after 1320), so Metochites advised him to keep practicing.[38] Philosophy was next and, according to Metochites, one had to pay special attention to Aristotle and his logics and physics: "[…] devote yourself especially to Aristotle, adding as much as / may be possible of your own by means of your productive mind. […] All the works this man composed […] I charge you, / learn well each and every one of them. But give […] / particular attention to his works on Logic / and Physics […]."[39] Finally, following Metochites' prescriptions, Gregoras should have continued his studies with mathematics and astronomy: "[…] afterwards, devote your labour also to the careful learning / of the *Quadrivium*, which you long / after, and again especially those of all-precious and / glorious Astronomy, which you have learnt from me, and / whereby you have become famous among wise men."[40]

As Bianconi noted, after Metochites' death in 1332, Gregoras seems to have been the only person in Constantinople competent in all disciplines of the *Quadrivium*.[41] In his own words, Gregoras claimed that as the only one who could preserve and perpetuate the knowledge of the mathematical sciences, he was compelled to start providing related instruction:

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37 Theodore Metochites, *Poem* 4, ed. and transl. Ševčenko/Featherstone, "Two poems," pp. 28–45.

38 Transl. Ševčenko/Featherstone. Theodore Metochites, *Poem* 4, lines 75–7: τοὔνεκα δὴ συνεχιζέμεν εἰν μελέτῃσι χρειώ, ἀδινά τ' ἐξ ἄρ' ἐθιζέμεν ἀνδρῶν ἐντεύξιος εὖ μάλα φωνὰν ἀρίστων εὐεπίης ἄσκησιν·

39 Transl. Ševčenko/Featherstone. Theodore Metochites, *Poem* 4, lines 136–8, 147–50: ἀτὰρ ἔπειτα διϊὼν πρόσθεν ὁδοῦ, πόνε' ἀμφὶ θεωρίαν ἑξῆς ὄντων φιλοσόφων ἀνδρῶν σπουδάσμασι, […] ἄσχολον ἶφι νόον προσίσχων καί τ' Ἀριστοτέλει πλέον, ἅμα τ' οἴκοθεν αὐτὸς ὅττι κεν ἐξῇ προστιθεὶς γονίμῳ ῥέα νούῳ. […] ἤτοι τοῦδε μὲν ἅ συντάξαθ' ἅπαντα […] σέ γ' ἕκαστ' ἐπιτέλλομ' ἅπαντ' εὖ μαθεῖν τἀνδρός· ἀτὰρ ὅσα Λογικ' ἀμφεπονήσατο καί τε Φυσικὰ […].

40 Transl. Ševčenko/Featherstone (revised). Theodore Metochites, *Poem* 4, lines 165–9: […] ἔπειτα πονοίης ἀμφί τ' αὖ τεττάρων βιβλίων Μαθηματικῶν εὐμαθίαν, ὧν κεν μάλ' ἔρασαι, τῶν δ' αὖ μάλιστ' Ἀστρουνομίης πουλυτίμοιο, μεγαλωνύμου, τὴν ἄρ' ἐμεῖο ἐκδεξάμενος ἀν σουφοῖσι γένου περίφαμος.

41 See Bianconi, "Erudizione e didattica," p. 506. Gregoras' teaching, scholarly, scribal, and editorial activities are closely associated with and continued by his student Isaac Argyros (d. *c.* 1375). Most recently on Gregoras' school, see Sklabenite, "Το διδασκαλείον του Νικηφόρου Γρηγορά."

> The frequent exhortations and entreaties of many became my incentive for this undertaking, since, among other rightful reasons, they proposed also that the past took away absolutely everyone and it did not leave at all among us anyone of the Hellenes, who would present to people's ears philosophy's most significant part, namely, the *Quadrivium*, and ⟨who⟩ would fill ⟨their⟩ craving souls full; and that thence, there is a rather imminent danger that ⟨our⟩ lot suffers a loss of what is the most beautiful of all things earth provides, namely the contemplation of the sun. For this reason, I opened a school and surrendered myself to toils and troubles [...].[42]

In sum, first, the framework of the four mathematical sciences is continually referred to by Byzantine authors from the ninth century to the end of the Byzantine millennium. Second, the μαθήματα are related to the study of philosophy in a twofold way: syllogistic usually precedes them, whereas they are themselves considered preparatory to the higher philosophical and theological studies. Nevertheless, the *Quadrivium* scheme does not manifest itself as an invariable standard uniformly applied throughout all times and places. On the contrary, what is actually included at any given instance in the study of the four sciences seems to elude us, even though their epistemic framework remains a valid and necessary tool for approaching the study of the natural world in Byzantium.

Finally, while we may describe the sociology of teaching and learning in relation to the process of transfer of knowledge in Byzantium, it is their phenomenology with which we struggle. The most obvious way to overcome this obstacle is quite simply to study all available manuscript and pictorial evidence that bears witness to teaching and studying the *Quadrivium* and its related disciplines such as geography, medicine, alchemy, and metrology. As it must be quite obvious to the reader, this would be a massive undertaking and much beyond the scope of the present chapter. What we can do, however, is to discuss what we know for certain and how we might proceed in studying this topic in future.

42 Leone 1982, pp. 299–300, *Letter* 114, lines 55–63: Ἐφόδια δέ μοι πρὸς τοὖργον αἱ συχναὶ τῶν πολλῶν συνωθήσεις καὶ ἱκεσίαι γεγένηνται τά τε ἄλλα προτείνουσαι δίκαια καὶ ὅτι καθάπαξ πάντας ὁ χρόνος φθάσας παρείλετο καὶ οὐδαμῇ γε οὐδένα τῶν καθ' ἡμᾶς ἀφῆκεν Ἑλλήνων, ὃς τὸ κυριώτατον τῆς φιλοσοφίας, τὴν τῶν μαθημάτων δηλαδὴ τετρακτύν, ἀκοαῖς ἀνθρώπων παράσχοι καὶ ψυχὰς πεινώσας ἐμπλήσειε, καὶ κίνδυνον ἐντεῦθεν μάλα πρόχειρον εἶναι ζημιοῦσθαι τὸ γένος, χρῆμα πάντων χρημάτων, ὁπόσα γῆ παρέσχεν ἡλίῳ θεᾶσθαι τὸ κάλλιστον. διά τοι τοῦτο καὶ διδασκαλεῖον αὐτὸς ἀνέῳξα καὶ κόποις ἐκδέδωκα ἐμαυτόν [...].

We can be certain that in any given period there is a given deposit of knowledge even though its parameters may vary. In other words, while the higher levels of mathematical astronomy may have not always been of primary concern in Byzantine society, nevertheless, they needed to maintain the level of mathematical education required for the purposes, for instance, of tax collection and land measurement, which in turn ensured a continuity between at least some levels of education in the mathematical sciences. Further, we know of teachers who were acquainted to a greater or lesser degree with the contents of the *Quadrivium* but, typically, they lacked exclusive specialization in the four μαθήματα. In fact, more often than not the success and popularity of Byzantine teachers was proportionately related to their ability to provide comprehensive instruction in a wide range of disciplines.[43] Finally, we can attest to the existence in Byzantium of literary practices related to knowledge organization that we would customarily recognize as indicators of systematic teaching activity, such as the production of new 'editions' of 'classical texts,' canonization and the existence of collections and commentaries.[44]

## 3 The Educational Context

There are many uncertainties about the nature or Byzantine secondary or higher education, but learning institutions or private teaching have been studied more extensively than other aspects of our subject.[45] There is no doubt about the fact that, beyond the false impression of continuity given by the ubiquitous mention of the *Quadrivium* disciplines, the contents and procedures of Byzantine scientific learning changed substantially from the ninth to the fifteenth century, beyond the regular presence of some texts used (indeed,

43 The teaching activity of Michael Psellos would be the most conspicuous Macedonian example of the ambition to attain all kinds of knowledge, a feature which continues during the Palaiologan era and is exemplified by the idealized discussions of *philomatheia* and *polymatheia*. For the latter, see Manolova, "Nikephoros Gregoras's *Philomathes* and *Phlorentios*," pp. 203–19. According to Loukaki, "Le profil des enseignants dans l'Empire Byzantin," p. 238, the lack of specialization of teachers during the sixth and the seventh centuries was their defining characteristic; cf. Pérez Martín, "Al calor del texto antiguo," p. 57.

44 Here we offer as a parallel the reasoning of Asper, "The Two Cultures of Mathematics," p. 128, in his discussion of ancient Greek mathematics.

45 For the only survey on scientific scholarship, see Vogel, "Byzantine Science," pp. 269–79. Also useful are the relevant pages in Wilson, *Scholars of Byzantium*, Constantinides, *Higher Education*, and Mergiali, *L'enseignement*, as well as Tihon, "Enseignement scientifique à Byzance."

in different ways) as introductions to secondary-level disciplines (see § 4.1). Although the more dynamic picture emerging from Palaiologan testimonia may be biased by the anonymity that characterized earlier periods, the general trend is towards a more extensive production of authorial texts, the implicit or explicit assimilation of knowledge produced in languages other than Greek,[46] and a higher level and increasing specialization in scientific matters.

Most of the teaching activity we can identify takes place under an institutional umbrella or position. What is usually labelled as "Imperial school" or even, wrongly, as "University" (!), is a changing institution of higher education supported by the Imperial administration[47] and heavily influenced by the personality of the teacher. In fact, only at the very beginning the school is identified by its location (Magnaura); afterwards the sources only provide the name of a teacher or the teacher's status. Nothing is revealed about the structure within which they were working. This suggests that teaching was a constituent part of the usual activities promoted within the framework of the Imperial administration when two conditions existed: first, the will of the emperor (or of influential members of the court) and second, a suitable and available scholar with the appropriate knowledge. On its side, the Patriarchate encouraged education that also involved scientific disciplines at a secondary level; but in the Palaiologan period, as we shall see, some patriarchal teachers were among the most skilled scholars of the time.

### 3.1 *Scientific Learning in Constantinople*

Evidence suggests that the school of the Magnaura, created in 843 by Caesar Bardas (d. 866), was the first Byzantine educational institution to emerge with the aim of organizing a complete *cursus studiorum*. According to the testimony of Theophanes Continuatus, Leo the Mathematician (*c.* 790–after 869) "took charge of the school of philosophy at the Magnaura, and his pupil Theodore was at the head of the room of geometry, Theodegios that of astronomy, and Kometas that of grammar which polished Greek speech."[48] This happened

46 This input comes from the east or the south, first from Baghdad and Egypt, then from Tabriz (see below); on behalf of the Western influence, we may mention the inclusion in Nikolaos Myrepsos' *Dynameron* of Italian/Latin recipes; see Ieraci Bio, "La sistematizzazione della farmacologia," pp. 307–8.

47 The internal political situation in the Constantinopolitan court left an ideological imprint on the higher education. On Byzantine learning as an affair of State, see Agapitos, "Teachers, Pupils," pp. 175–76; on the general framework, Markopoulos, "The school in Byzantium."

48 Theoph. Cont. 4.29 (p. 272, lines 16–19). Cf. Genesios 4.17: "The Caesar Bardas greatly honored wisdom and learning, even though he was more interested in its display. He gathered wise men at the Magnaura, some of them philosophers and geometricians,

during Theodora's regency (842–855), but previously the emperor Theophilus (805–842) had appointed Leo as a teacher at the school of the Forty Martyrs,[49] where his teaching was already focussed on scientific topics. Apparently, the creation of a teaching position for him in Constantinople had been the imperial response to the interest of the Caliph in Baghdad in Leo's geometrical knowledge. According to Theophanes Continuatus, Leo "instructed the pupils who came to him making use of a simple lodging and residence, teaching whichever subject they desired."[50]

Scientific book production in ninth-century Constantinople is generally linked to this all-rounder professor, and is a testimony to the study of a corpus of scientific treatises among which Ptolemy's *Almagest* and *Handy Tables* occupy a prominent place.[51] Nevertheless, Leo did not leave behind writings that might give us an insight into the level of his teaching.[52] In any event, however, the framework established with the help of his authority long continued thanks to Photios (*c.* 810–*c.* 893), on whose scientific teaching, after discarding a phantom Patriarchal academy, we only have two explicit testimonies, but no texts.[53] Finally, the science teachers of the so-called "Imperial School" during

other astronomers, and still other grammarians, and instructed them to teach all who came for free. And he paid such great attention to these matters, that he appointed the great philosopher Leo to teach philosophy, his student Theodore to teach geometry, Theodegios to teach astronomy, Kometas grammar, and all were supported by adequate Imperial salaries. He diligently attended their lectures and considered the aptitude of each of the students, and all this gave him the highest hopes. The salaries gave the teachers a great incentive to care for their students, and hence the seeds of learning that he planted resulted in a bounty for us today and secured the immortality of his memory." (transl. Kaldellis, pp. 86–87). Cf. Speck, *Die Kaiserliche Universität*, pp. 1–13.

49 Magdalino, "The Road to Baghdad," pp. 199–201; Signes Codoñer, *The Emperor Theophilos and the East*, pp. 434–48. Cf. Theoph. Cont. 4.27 (Greek text, p. 268.83–86; transl. p. 269): "(The emperor) summoned him (Leo), and he became rich and was urged by the emperor to teach in public in the church of the forty Martyrs." Speck, "Further Reflections," pp. 189–90, n. 14, does not accept the veracity of Leo's appointment to the school of the Forty Martyrs. The church had an eminent position in a very central place of the City, near to the Chalkoun Tetrapylon, and was linked to the legal practice in Theophilos' times and in the eleventh century; see Magdalino, "Medieval Constantinople," pp. 36–38.

50 Theoph. Cont. 4.27, p. 264.8–9 (transl. p. 265). The same boasting occurs in Michael Italikos (fl. 1136–1166)'s, ep. 5 Gautier, when he claims to teach whatever medical subject students ask for.

51 See Vitrac, "Quand? Comment?," pp. 134–38.

52 A summary of the textual evidence in Pingree, "Leo the Mathematician"; cf. Acerbi, "Types, Function, and Organization," pp. 125–27 and 164–66, with important clarifications.

53 In cod. 187 on Nicomachus' *Theology of Arithmetic* of his *Myriobiblon* (last paragraph, see Henri vol. 3, p. 48, Schamp, "Du verbe au Verbe," pp. 7–8), he brings his teaching on geometry, arithmetics and other mathematical sciences into line with Ammonios'; students who frequent his house are able to comprehend Nicomachus' theorems with

Constantine VII's reign (Nikephoros Patrikios who lectured on geometry and Gregorios the Asekretis on astronomy) remain just names for us.[54]

Around 1045, Michael Psellos (1017/8–1076 or *c.* 1078) was appointed *proedros* and then *hypatos ton philosophon*, a pretentious title for a charge probably created for him but that survived until the fourteenth century.[55] Psellos taught privately before this appointment which placed him at the top of the intellectual life of Constantinople and was a sign of recognition of his extraordinary personal resources.[56] We do not have any evidence as to whether his school had a name or as to whether he taught continuously until the 1070s. At least his enormous literary production gives us an accurate picture of his teaching, as we will see in the subsequent sections.[57] In fact, not only Psellos' writings speak extensively about his lessons, students, and activities,[58] but also manuscripts attribute to him brief texts, treatises (sometimes in epistolary form) or poems, on a broad spectrum of subjects from medicine to physics.[59] Much of this still awaits scholarly attention, but even now we can express our admiration for the odd mixture of boundlessness curiosity and hyperactive urgency to convey knowledge. We might label the corpus of his writings as a high-level dissemination of science, as opposed to the more specialized Palaiologan contribution to the arithmetical and astronomical knowledge.[60] In this sense, Psellos embodied the Byzantine contribution to the development of the Greek scientific heritage.

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exactitude; in ep. 290 to pope Nicholas, Photius describes the pleasure of staying home and sharing with the students the experience of learning (ed. Laourdas, lines 63–71).

54 Speck, *Die Kaiserliche Universität*, pp. 22–28; Tihon, "Enseignement scientifique," p. 96.

55 Constantinides, *Higher Education*, pp. 113–32.

56 Wolska-Conus, "Les écoles de Psellos et Xiphilin," Kaldellis, "The Date of Psellos' Theological Lectures," pp. 144–46, with previous bibliography.

57 See especially, Psellos, *Philosophica minora*, vol. 1; Pontikos, *Anonymi miscellanea philosophica*.

58 See Kyriakis, "Student Life in 11th-century Constantinople"; Lemerle, *Cinq Études*, pp. 212–27.

59 On Psellos' scientific production and interests, see Moore, *Iter Psellianum*, pp. 252–65, Telelis, "Οι λόγιοι του 11ου αιώνα"; Pérez Martín, "The Transmission of Michael Psellos' Writings on Meteorologica," Jeffreys/Lauxtermann (eds.), *The Letters of Psellos*, pp. 187 (KD 42), 351–52 (S 86). Psellos' zeal to promote philosophy in all its ramifications has been called by Duffy, "Hellenic Philosophy in Byzantium," p. 152, his "lonely mission," echoing Psellos' own words: "I am a lone philosopher in an age without philosophy." See also Agapitos, "Teachers, Pupils," pp. 180–81, Papaioannou, *Rhetoric and Authorship*, pp. 30–36, and especially the "intellectual autobiography" inserted by Psellos in his *Chronographia* (6.36–46).

60 See, for example, Redl, "La chronologie appliquée de Michel Psellos," Tannery, *Mémoires scientifiques*, vol. 4, pp. 261–82 (No. 9–11).

Psellos' thirst for knowledge was transferred to scholars such as Symeon Seth (fl. 1070–1100). Michael Italikos (fl. 1136–66) also followed in Psellos' tracks when he studied the *Chaldean Oracles* and other texts of the kind that enriched the medicine he practiced and taught.[61] The Komnenian emperors, however, do not seem to have encouraged higher scientific studies, even though the *Τετρακτύς*, as we shall see, continues to be mentioned like a mantra intended to prove the completion of the education cycle.[62] As a matter of fact, in the Komnenian century, apart from some astrological poems with didactic purpose,[63] and the *Parekbolai* of Eustathios of Thessalonike (*c.* 1115–1195/6) to Dionysius Periegetes,[64] classroom work on scientific texts is still waiting to be rescued from the surviving books. Nevertheless, soon before the disaster of 1204, the School of the Holy Apostles described by Nikolaos Mesarites (*c.* 1163/4–after 1216) guaranteed a secondary-level teaching in the *Quadrivium* disciplines.[65]

Nikephoros Blemmydes (1197–1272), the protagonist of higher education during the period of the Empire of Nicaea, shared with Psellos and some Komnenian scholars his predilection for natural science, as his *Physike epitome* suggests.[66] However, Blemmydes did not leave behind astronomical or geometrical texts, even if he had studied those subjects;[67] alternatively, his choice in the *Epitome* distances itself from the Psellian layout by giving a systematic exposition of Aristotelian physics that sums up the commentaries on the latter and introduces new authors such as Cleomedes. The work seems to be more appropriate to a personal programme of studies than an actual teaching

61 On Italikos, see Nesseris, *Η παιδεία στην Κωνσταντινούπολη*, vol. 1, pp. 279, 328–31, 337–40, 347, and vol. 2, pp. 337–40. On Psellos' influence over Italikos and how the later practiced medicine, see Duffy, "Reactions of Two Byzantine Intellectuals," pp. 91–95.

62 On scientific teaching in the twelfth century, Nesseris, *Η παιδεία στην Κωνσταντινούπολη*, vol. 1, pp. 273–361, with an accurate analysis of outnumbered testimonies; cf. also Nesseris, "Mathematics in Twelfth-Century Byzantium."

63 See Caudano, "An Astrological Handbook."

64 Ed. Müller. Eustathios' commentary belongs to the realm of rhetoric, but he proves his awareness of the scientific debate on some issues concerning the shape of the inhabited world; he mentions Ptolemy, Poseidonios, and other ancient geographers.

65 Downey, "Nikolaos Mesarites." See also chapter 3 of this volume.

66 See Lackner, "Die erste Auflage des Physiklehrbuches," pp. 164–65; Golitsis, "Georges Pachymère," pp. 62–63; Valente, "The Doctrine of Winds in Blemmydes." On the education promoted by the emperors of Nicaea, see the PhD of Schoina, *Η παιδεία στην αυτοκρατορία της Νικαίας*. It is no mere chance that the Laskarid administration encouraged the preservation of Psellos' legacy and, hence, his influence through the copy of Oxford, Bodleian Library, Barocci 131 and other manuscripts. See Pérez Martín, "The transmission of some writings by Psellos."

67 Constantinides, *Higher Education*, p. 12. In his *Autobiographia*, Blemmydes does not speak about the content of his own teaching.

schedule, but when the emperor John Vatatzes (1222–1254) forced him to accept five students and to train them,[68] natural sciences were probably part of the content of that training.

Luckily enough, Blemmydes taught George Akropolites (1217–1282), who, in turn, taught Theodore II Laskaris (1221/2–1258) "the whole curriculum of philosophy" (including μαθηματικαὶ ἀποδείξεις)[69] and after 1261 became not only the 'strong man' in the imperial administration but also the one responsible for the training of its future members.[70] Once again, we do not know how or where his teaching was organized, but at least we can be certain that he explained Euclid and Nicomachus, using them as the introductory texts for the study of geometry and arithmetic [see below].[71] The exponential growth of copies of these writings in the second half of the thirteenth century reflects the centrality granted by the imperial power to a selection of its cadres according to their academic education.[72] Also, from 1261 on, the picture of scientific teaching in Byzantium is no longer a dashed line, but a small galaxy of dots, and, if it is still mostly elusive, we are much better informed about people with a scientific training, people who appear to be travelling, changing their residences, reinventing themselves if the political situation required it, and accepting an ecclesiastical office or seeking refuge in a monastery.[73]

For the first time, we can be sure that more than one person in the same generation studied or taught the same scientific subjects, and this led to confrontations, the extent of which we are unaware. Conflicts in fact were the daily bread for Palaiologan scholars,[74] who could also discuss in a virtual way

68 Nikephoros Blemmydes, *Autobiography*, 1.49 (English transl. Munitiz, pp. 71–72). Munitiz, *ibidem*, pp. 36–37, on Blemmydes teaching, first privately, later at his monastery and finally to Theodore II Laskaris; cf. Constantinides, *Higher Education*, pp. 7–9, 14–17; Macrides, *George Akropolites, The History*, p. 9.

69 See Laskaris' *Encomium for Akropolites* (from 1252), ed. Markopoulos, "Θεοδώρου Β' Λασκάρεως ἀνέκδοτον ἐγκώμιον," p. 117, lines 203–11. On Akropolites' *cursus studiorum* and later teaching in Nicaea, Constantinides, *Higher Education*, pp. 17–19; Macrides, *George Akropolites, The History*, pp. 8–11.

70 Constantinides, *Higher Education*, pp. 31–35; Macrides, *George Akropolites, The History*, pp. 12–14.

71 Gregory of Cyprus, *Autobiography*, ed. Lameere p. 185, 15–17.

72 From the Macedonian and Komnenian periods: no copies of Geminus, Ptolemy's *Geography* or Cleomedes; 4 copies of Aratos. From the first Palaiologan century: 4 copies of Geminus, more than 15 copies of Ptolemy's *Geography*, around 17 copies of Aratos, and around 30 copies of Cleomedes.

73 Pérez Martín, "Le conflit de l'Union des Églises."

74 See p. 102, § 7.4.

in the blank space surrounding the ancient scientific texts.[75] But the indirect proof of the existence of this scientific arena is the fact that scholars began to write down their names with the notes they added in the margin of scientific texts. They did so in open competition with the object of obtaining recognition for their findings and corrections.[76] The *hypatos ton philosophon* "chief of the philosophers" John Pediasimos (d. 1310/4) and Maximos Planudes (d. 1305) converged on either the study or the teaching of texts such as Euclid or Cleomedes, *De cyclica theoria*.[77] John Pediasimos, the imperial teacher of philosophy and the *Quadrivium*, had to enter into competition with the brilliant Maximos Planudes (who became a monk after 1283, although still involved in the imperial service during the reign of Andronikos II).[78] His modest contribution,[79] however, could not eclipse the gifted input of Planudes and was itself diminished by Planudes' innovative work.[80] Planudes himself left behind at least one student interested in arithmetic, namely, Manuel Moschopoulos (fl. *c.* 1300).[81] Nevertheless, Planudes 'editorial' work on difficult authors such

75 As did Maximos Planudes and John Pediasimos in the margins of the Euclid Florence, Biblioteca Medicea Laurenziana, Plut. 28.2; see Pérez Martín, "L'écriture de l'hypatos," pp. 117–19.

76 Besides the case mentioned already of the Florentine Euclid (where Pediasimos, as in other manuscripts, establishes his authorship with the words τοῦ ὑπάτου), Planudes also wrote his name at the beginning of a scholium to *Elementa* X in Vienna, Österreichische Nationalbibliothek, phil. gr. 31, fol. 144v (sch. X.223 Heiberg, who attributed it to a student of Planudes, as usual); cf. Pérez Martín, "El Vindob. phil. gr. 31." Isaak Argyros wrote in the margin of Ptolemy's *Harmonica* in Vatican, Biblioteca Apostolica Vaticana, gr. 176, fol. 138v, that the old copies of the text were faulty and that it was Argyros (using the third person!), and not his teacher Gregoras, who corrected it; indeed, Gregoras' reconstruction of two chapters of the text had already been criticised by Barlaam (his refutation in Düring, *Die Harmonielehre*, pp. 112–21). Also, John Chortasmenos wrote his name before his scholium to Arist. *An. pr.* in Paris, Bibliothèque Nationale de France, gr. 1846, fol. 151.

77 See Todd, "The Manuscripts of John Pediasimus," pp. 276–80.

78 On Planudes, see Constantinides, *Higher Education*, pp. 66–89.

79 On Pediasimos scientific writings, Constantinides, *Higher Education*, pp. 117–25; Acerbi/Pérez Martín, "Les études géométriques." He wrote a commentary on Cleomedes (ed. Caballero Sánchez, *El Comentario de Juan Pediásimo*) and a metrological compendium (the so-called *Geometry*) based on Heron, among other works.

80 See Allard, *Maxime Planude, le "Grand calcul selon les Indiens,"* Pérez Martín, "Maxime Planude et le *Diophantus Matritensis*," Mondrain, "Traces et mémoire," pp. 16–18. On Planudes' copy of Theon's commentary on the *Almagest* (Paris, Bibliothèque Nationale de France, gr. 2396), see Mondrain, "Maxime Planude, Nicéphore Grégoras"; on his notes in Ptolemy Vatican, Biblioteca Apostolica Vaticana, gr. 1594, see Acerbi, "Une topographie du Vat. gr. 1594."

81 Tannery, "Le traité de Manuel Moscopulos sur les carrés magiques. Texte grec et traduction," *Mémoires scientifiques*, vol. 4, pp. 27–60; Constantinides, *Higher Education*,

as Diophantus or Aratos existed at such a high level that it was too specialized to belong in the schoolroom.

Contemporaneously, the patriarchal school hosted the teachings of Georgios Pachymeres,[82] but shortly after (in 1313) only by chance Theodore Metochites could find someone who was able to explain to him mathematics, astronomy, and harmonics. This was Manuel Bryennios (fl. beginning of the fourteenth century), who perhaps had colluded with the patriarchal teacher in a discussion about the seven wandering stars.[83] After Metochites' death, Nikephoros Gregoras remained as custodian of the library at the monastery of Chora, where Planudes' books helped to build a reference centre of erudition for at least one more generation.[84] Even if there is no written evidence for that, it is unquestionable that Gregoras had access to a substantial number of books that had passed through the hands of Maximos Planudes.[85] The hypothesis that Planudes was the monk Maximos of Chora is made more plausible by a Latin note (dated somewhat later) written in a manuscript of Ptolemy's *Geography* which remembers him with admiration.[86] Around 1290–93 Planudes was asking for financial help to restore the monastery of the Five Martyrs on Mount Auxentios (a holy mountain with hermitages and monasteries located near Constantinople), and in 1299–1301 was living at the monastery of Akataleptos in Constantinople, while the work he did restoring manuscripts from a ruined imperial monastery was continued at Chora.

There, Nikephoros Gregoras managed to establish himself as the only science teacher in Constantinople after, according to his own testimony, he defeated Barlaam of Calabria (*c.* 1290–1348), a better mathematician and astronomer than he, in 1331–33.[87] When Nikolaos Kabasilas (1319/23–post 1391) moved to Constantinople from Thessalonike in order to complete his education, and he dedicated himself to the study of Ptolemy with such passion that he fell ill, Gregoras was certainly the professor who introduced him to this field

p. 108. His composition of the treatise on magic squares may point out that Moschopoulos also taught arithmetics.

82 See § 4.2.2.

83 Constantinides, *Higher Education*, pp. 96–97, 157; Bydén, *Theodore Metochites'* Stoicheiosis astronomike, pp. 228–30; on the contemporary criticism of his learning, Acerbi/Pérez Martín, "Gli scolii autografi di Manuele Briennio," p. 104.

84 Ševčenko, "Theodore Metochites, the Chora."

85 Bianconi, "La biblioteca di Cora."

86 See chapter 7 of this volume.

87 Polemis, "Ἡ πρὸς τὸν Βαρλαὰμ διένεξις τοῦ Γρηγορᾶ"; Tihon, "Il Trattato sulla data della Pasqua di Barlaam"; Tihon, "Barlaam de Seminara, Traité sur la date de pâques"; Manolova, "Astronomy as Battlefield?"

of study.[88] The momentum he developed fell away until the appearance of Isaak Argyros (d. *c.* 1375), who inherited the interests of the master, to the point of repeating some of Gregoras' contributions on the astrolabe, the Paschal computus or Ptolemy's *Harmonics.*[89] But at the same time another, darker character appears to breathe down their necks: Malachias, a scholar who belonged to the circle of the former emperor John Kantakouzenos and therefore to the 'hesychast' opposition to Gregoras and Argyros. He copied the scientific writings of the Chora school in Vatican, Biblioteca Apostolica Vaticana, gr. 208, but felt obliged to excuse himself for doing so in a note on fol. 15 that concentrates upon the sanctimoniousness of the winner in the theological quarrels.[90]

Since it became possible to identify the handwriting of Palaiologan scholars in a substantial number of scientific manuscripts a better understanding of their work has been granted, especially on mathematical and astronomical issues.[91] For example, it makes clear that John Chortasmenos (d. 1431)[92] had open access to the Chora legacy, and it was he who benefitted in 1397–1400 from the learning of his master Michael Balsamon (another teacher who is known only through others' references, but has no known publications). Both of them were ecclesiastics whose teaching continued that of Pachymeres at the Patriarchal school as *katholikoi didaskaloi.* Previously, Theodore Meliteniotes (d. 1393), a *didaskalos ton didaskalon* whose contribution was mainly

88 Acerbi/Pérez Martín, "Les études géométriques."

89 The *Methodos* on the astrolabe is from 1367/8, ed. Delatte, *Anecdota Atheniensia*, vol. 2, pp. 236–53; for the Paschal computus, see Tannery, "Notice sur les deux lettres arithmétiques," p. 136, and Schissel, "Die Osterberechnung"; for the work on Ptolemy, see Düring, *Die Harmonielehre*, pp. lxxxviii–ix and lxvi.

90 See Mercati, *Notizie di Procoro e Demetrio Cidone*, p. 233. On the identity of the scribe, see Mondrain, "Traces et mémoire," pp. 22–25, and Mondrain, "L'ancien empereur," pp. 278–92.

91 For instance, Planudes' work on mathematical texts has been identified in the MSS Madrid, Biblioteca nacional de España, Mss/4678, Florence, Biblioteca Medicea Laurenziana, Plut. 28.2, Vienna, Österreichische Nationalbibliothek phil. gr. 31, Milan, Biblioteca Ambrosiana, & 157 sup.; cf. Allard, "L'*Ambrosianus* & 157 sup."; Pérez Martín, "Maxime Planude et le Diophantus Matritensis," Pérez Martín, "L'écriture de l'hypatos"; Pérez Martín, "El Vindob. phil. gr. 31." On astronomical manuscripts copied or corrected by Nikephoros Gregoras, see below, n. 131 on Vat. gr. 1087; on Paris, Bibliothèque nationale de France, gr. 2345 and 2396, Paris, Bibliothèque nationale de France, Coislin 173, Vat. gr. 1594, Venice, Biblioteca Nazionale Marciana, gr. 312 and 325, Mondrain, "Maxime Planude," Bianconi, "La biblioteca di Cora."

92 Mondrain, "Traces et mémoire," pp. 13–15; on Chortasmenos, see chapter 6 of this volume.

theological, composed a famous *Astronomical Tribiblos* that was not necessarily linked to his teaching.[93]

### 3.2 *Study Trips*

The *Tribiblos* seems to be a very derivative work and among the sources Meliteniotes drew from, there were some adaptations of Persian astronomical calculations. From the beginning of the fourteenth century, the main Alexandrian tradition of Byzantine astronomy was enriched by the contribution of the Islamic tradition which leads us to what, as far as we know, is an *unicum* in the history of Byzantine science: the testimony of a man who travelled to Tabriz in order to learn astronomy and the (false) creation of a scientific school outside Constantinople.

The figure of the hieromonachos Gregory Chioniades (*c.* 1240/50–*c.* 1320?) still needs clarification.[94] George Chrysokokkes (fl. 1335–1350) states in his *Persian Syntaxis* (an introduction to astronomy written around 1346)[95] that Chioniades travelled to Persia to study astronomy.[96] His destination was Tabriz, where an observatory had been set up by the Ilkhanid ruler Ghâzân Khân (1295–1304). The anonymous astronomical material preserved in Vatican, Biblioteca Apostolica Vaticana, gr. 211 and Florence, Biblioteca Medicea Laurenziana, Plut. 28.17[97] is explicitly the Greek *mise au point* of the teaching of Shams Bukharî around 1295/6. Since it coincides with Chioniades' stay in Tabriz, it may be his work, even if manuscripts do not indicate who translated or reworked Shams' teachings.[98]

On his way to Tabriz, Chioniades made a stop in Trebizond and obtained the financial support of the emperor John II Komnenos (1292–97). In exchange, he was asked to teach in the Pontic city, something he did perhaps intermittently,

93 As Mergiali, *L'enseignement*, pp. 154–55, points out. But Tihon, "Les tables astronomiques," p. 482, has argued that it was Meliteniotes who introduced Persian astronomy into the educational curriculum in Byzantium.

94 Pingree, "Gregory Chioniades," erroneously attributed to him astronomical notes in Vatican, Biblioteca Apostolica Vaticana, gr. 191, entangled the chronology. Bydén, *Theodore Metochites'* Stoicheiosis astronomike, pp. 242–52, follows him. On his philosophical writings, see especially Kavrus-Hoffmann, "Catalogue," pp. 217–26.

95 On the *Persian Syntaxis*, see Mercier, "The Greek 'Persian Syntaxis'"; Tihon, "Les tables astronomiques persanes," pp. 471–79; Mercier, "Tables islamiques à Byzance," pp. 418–19.

96 Lampsides, "George Chrysococcis," pp. 315–16; on Chrysokokkes' writings, Mercier, "The Greek 'Persian Syntaxis.'"

97 See Pingree, *The Astronomical Works of Gregory Chioniades.*

98 Tihon, "L'astronomie byzantine," pp. 615–18; Tihon, "Traités byzantins sur l'astrolabe," pp. 333–35.

since at some period he found himself in Constantinople.[99] The information about the contents of his teaching is scanty, but this circumstance has not prevented Papadopoulos from reconstructing a fantastic international school of astronomy in Trebizond from the already mentioned testimony of George Chrysokokkes.[100] The preserved evidence which may be related to Chioniades' teaching is in fact very scanty: a manuscript with Psellos' *De omnifaria doctrina* probably copied in Trebizond (Paris, Bibliothèque Nationale de France, gr. 2087) and a horoscope in a manuscript that belonged to Andreas Libadenos (fl. 1341–61).[101] But books certainly flowed from Constantinople to Trebizond in the luggage of the officials whose lives went on between both cities.[102] Nevertheless, Chioniades' wisdom had vanished by 1361 when no one in Trebizond was able to forecast an eclipse.[103]

### 3.3 *Technical Knowledge and Specialized Schools*

In histories of science, the limited space granted to the Byzantine contribution is mainly devoted to its role as a mediator between Greek antiquity and the modern era, supplemented by the assimilation of Persian astronomy through Trebizond and the introduction of Hindu numerals. Obviously, we cannot deny that Byzantine science revolved around the written legacy of ancient Greek science. Even if Byzantine civilization is very different from that of Greek antiquity, they share with the Western world a defining feature, namely, the distinction between theory and praxis, *episteme* and *techne*, or in other words between sciences developing within a conceptual or philosophical frame and practical sciences.[104] This dichotomy increases when praxis joins superstition and we get the pairs astronomy/astrology, medicine/art of healing, computation/numerology, and so on.

Scientific learning might have repeated this approach, but we are still far from being certain of how learning in some specific matters actually took place. For example, warfare may have been a traineeship in the family environment and then progressively in military campaigns, but our information is scanty.[105] Likewise, specialists fail to agree on how architects or master-builders

99 Savvides, *Ιστορία*, pp. 202–4; Bydén, *Theodore Metochites'* Stoicheiosis astronomike, pp. 242–51; Rosenqvist, "Byzantine Trebizond," pp. 40–41; Magdalino, *L'Orthodoxie des astrologues*, pp. 148–50.

100 Papadopoulos, "Γρηγορίου Χιονιάδου," pp. 158–69.

101 Munich, Bayerische StaatsBibliothek, gr. 525, fols. 155–172 (*Almanac*, ed. Mercier).

102 See Savvides, *Ιστορία*, pp. 183–207.

103 See Bryer, "Eclipses and Epithalamy," p. 350.

104 Asper, "The Two Cultures of Mathematics," impinges on this duality.

105 See Métivier, "Culture familiale et savoirs d'État," on the role of aristocratic families in the military education of their offspring.

acquired their skills (or even the nature of the skills themselves!). Some art historians prefer to consider construction work as a handicraft disregarding outlines or plans and therefore independent of any geometrical or arithmetical learning.[106] They forget that Isidoros of Miletus (one of the architects commissioned by the emperor Justinian to rebuild Hagia Sophia, d. before 558) was himself a professor of mechanics or geometry and that Book 8 of Pappus' *Collection* is an introduction to the "μηχανικὴ θεωρία" (the term for architectural or engineering studies).[107] According to Pappus,

> [...] [the manual part of the discipline is composed] of work in metals, construction, carpentering, and the art of painting, and the practical executions of these matters. The man who has been trained from his youth in the aforesaid sciences as well as practised in the aforesaid arts, and in addition has a versatile mind, will be, they say, the best inventor of mechanical devices (or mechanical engineer) and builder.[108]

In spite of the similarities in the planning of fortress and cities in Mesopotamia and Syria many experts on Byzantine architecture show a great deal of skepticism, about whether in the central decades of the sixth century a corps of imperial *mechanikoi* or architects existed.[109] A closely related profession, military engineering, is even less well known, even though a corpus of treatises on construction of war machines has been preserved.[110]

We have already presented the institutional framework of the learning associated with civil servants, which had a theoretical bias very distant from the need of the State to calculate taxes and measure the land that was the main source of its wealth. But some interesting hints on practical learning may be found in the Byzantine treatises on geodesy; they are described sometimes as

106 Buchwald, "The Geometry of Middle Byzantine Churches," pp. 299–300; Striker, "Applied Geometry in Later Byzantine Architecture."

107 See Downey, "Byzantine architects," pp. 106–14; the spreading of the text was certainly limited—we know just one Byzantine manuscript, Vatican, Biblioteca Apostolica Vaticana, gr. 218.

108 Transl. by Downey, "Byzantine architects," p. 107.

109 Zanini, "Technology and Ideas: Architects and Master-builders," pp. 389–94; cf. Buchwald, "Byzantine Town Planning—Does it Exist?"; Cuomo, *Technology and Culture*, pp. 134–245. This matches with a Constantinian disposition (*CTh* XIII.IX.1.334) mentioned by Jones, *The Later Roman Empire*, vol. 2, p. 1013: Constantine ordered that young men should be encouraged to learn the art of architecture by the grant of immunity for their parents and scholarships for themselves, he stipulated that candidates should be of about 18 years of age, and should already have received a liberal education.

110 Haldon, *Warfare, state*, p. 52.

τοῦ μέτρου διδασκαλία and they claim to be used by trainee notaries, while the legal profile of the codices suggests the same thing.[111] Different scholars tried to improve the trivialization of this learning by using Hero of Alexandria's texts. Michael Psellos advised his former student Pothos to draw upon the geometry he learned at school in order to arbitrate a land dispute.[112] In its opening lines, John Pediasimos' *Σύνοψις μετρήσεως καὶ μερισμοῦ γῆς* presents itself as inspired by Heron's *Geodaesia* in an attempt to clean up what he calls "silly little theorems" of geodesy. Argyros' treatment of the subject takes the same approach: he wrote a *Method of Geodaesia, sc. land measuring, certain and brief*,[113] that sometimes disguises as a letter *to Kolybas in Mitylene, who enquired about it.*

Amongst the disciplines that do not belong to the *Quadrivium*, medicine is certainly the one study about which we are better informed.[114] Since knowledge about health was socially sensitive, it is only natural that its practitioners were sanctioned to do their job and that the exercise of the profession was somehow regulated.[115] On the other side, its learning required long practice: John Aktouarios (*c.* 1275–*c.* 1330) while still a student attended a *phrontesterion* (probably a monastic hospital) daily to practice medicine. In fact, monasteries were the natural places for the healing of diseases and hence for medical

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111 Lefort et al., *Géométries du fisc*, p. 246 (on the term τοῦ μέτρου διδασκαλία) and pp. 248–49 on the notarial context. These texts, the oldest preserved describing the procedures of the land measurement, are presented here not as scientific but as instruments of the fiscal geometry. Lefort, "Mesure fiscale de la terre à Byzance," in id., *Société rurale et histoire du paysage à Byzance*, Paris 2006, pp. 479–89, on the real nature of the tax treatises, that has nothing to do with the geometrical science, but propose elementary and wrong (efficient though) receipts to evaluate land surfaces, see Lefort, "Mesure fiscale."

112 Kurtz/Drexl, ep. 42, pp. 69–70, cf. Jeffreys/Lauxtermann (eds.), *The Letters of Psellos*, p. 187, dating the letter from 1060–66. Psellos wrote a *Γεωμετρία διὰ στίχων* (POE.58 Moore, 285 political verses) which introduces the land measuring starting from the value of some units; ed. Westerink, *Poemata*, pp. 415–24, and Lefort et al., *Géométries du fisc*, pp. 184–201. According to Lefort (*ibidem*, p. 251), Psellos' words are ironical, but the testimony still shows the proximity of geometry and fiscal measuring.

113 Heiberg, *Heronis quae feruntur stereometrica et de mensuris*, pp. xcviii–cii; cf. Lefort et al., *Géométries du fisc*, pp. 154–67 and 250.

114 See chapter 10 of this volume.

115 Hohlweg, "John Actuarius," p. 124, on the interpretation of κηρύγματα (in Georgios Lakapenos, ep. 10, to John Aktouarios, still a medicine student) as the certification of medical competence representing the crowning point of the learning process. On John Aktouarios, Kourouses, *Τὸ ἐπιστολάριον*, and the edition of his *De urinis* Book 1 by Georgiou. Cf. Grumel, "La profession médicale," on the synodal sentence dating from 1134–43 explicitly expressing that the medical doctor had to study, practice, be examined and obtain a diploma. We do not know the context of Michael Italikos' teaching of medicine; see Gautier, *Michel Italikos, Lettres et discours*, pp. 19–21.

schools.[116] Byzantine evidence is limited to two Constantinopolitan monasteries:[117] the Pantokrator in the Komnenian period, whose typikon of 1136 "prescribes that there should be a teacher to teach the principles of medical knowledge"[118] and Saint John Prodromos of the Petra in the Palaiologan period, especially before 1453.[119] Although the evidence is scattered, the well-established dignity of *aktouarios* would unite the office of court physician and head of a school of medicine.[120]

## 4 Scientific Books: the Path of Learning

Most Byzantine books were intended for prayer or learning, and very few contained entertaining literature—the role of what nowadays is called literary fiction was then played by oral narratives or poetry performed in private. This fact would suggest that we should look for the educational component in every scientific text read or written in Byzantium and consider any scientific book as potentially educational in itself. In many cases Byzantine scientific texts were born in a teaching/learning context and we can be certain that their main aim was to be understood or consulted in order to acquire the skills deemed necessary to complete an education or to perform a job.

116 According to Nutton, "From Galen to Alexander," p. 10, there is no evidence of a teaching function in the hospital before the eleventh century. On the medical training through apprenticeship with a physician, see Duffy, "Byzantine Medicine," p. 21.

117 What Mesarites describes in the Holy Apostles (§ 42.2–5, transl. Downey, "Nikolaos Mesarites," pp. 894–95) is not a medicine school, but the teaching of medical or biological notions in the context of a secondary school. He writes in detail of the contents, suggesting that he is actually speaking about his own learning.

118 See Thomas/Constantinides Hero, *Byzantine Monastic Foundation Documents*, p. 765: § 55; the teacher must attend "to the task of teaching and teach the student doctors of the hospital the knowledge of medicine in a consistent and zealous manner." Cf. *ibidem*, p. 760, § 48, on the inner promotion of the auxiliary doctors, suggesting that the teaching of medicine was addressed to doctors-to-be of the monastery.

119 In the fourteenth century, the intense copying of medical manuscripts suggests learning, while in the last years of Byzantium John Argyropoulos taught medicine to some students who produced a consistent group of manuscripts suggesting they had an interest in some epistemological and methodological issues; see Mondrain, "Jean Argyropoulos," among other contributions to the subject; Pietrobelli, "Variation autour du Thessalonicensis Vlatadon 14"; Ieraci Bio, "Giovanni Argiropulo." Petit, "The fate of a Greek medical handbook," pp. 66–68, suggests that some Argyropoulos' students created a study programme based on Galenic works. More work is to be done on these medical texts linked to the Petra.

120 See Grumel, "La profession médicale," pp. 44–45.

Unlike the rich testimony of Egyptian papyri that provides an insight into materials used in schools, i.e. mainly lists of geometrical or calculation problems,[121] Byzantine manuscripts rarely possess this ephemeral kind of text, since in order to be stocked in modern libraries, books needed to meet some requirements of size (for the binding), condition, and legibility.[122] Communal books, if they existed in the Byzantine school,[123] were destined to perish sooner or later in the hands of students, just as liturgical books did in the hands of priests.[124] Therefore, materials accessible to us are now biased by their material quality and the care with which they were handled. This excludes the most common school books, especially those produced before the Palaiologan period. It is still very possible that what we now describe as flyleaves of Byzantine manuscripts were originally loose leaves. Hence sometimes they display elementary and short learning texts, astronomical calculations for a specific period of time[125] or even reference figures such as Pythagoras' *nymphe* (Fig. 2.1). Groups of arithmetical and geometrical problems, however, presented according to their content and in an increasing order of difficulty, were organized and copied in order to turn them into reference books for a teacher or for someone fond of this kind of learning. That is the case with San Lorenzo de El Escorial,

121 Cuomo, *Ancient Mathematics*, pp. 212–14; Jones, "Mathematics, Science, and Medicine in the Papyri," p. 339: "The most obvious difference between the evidence of the medieval textual tradition, which was heavily influenced by the intellectual elite of the later Roman and Byzantine periods, and that of the papyri is that much of the papyrological record has a direct bearing on practice and applications."

122 Pérez Martín, "Byzantine Books," p. 43. One exception is found in Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 1038 (thirteenth century), where three figures concerning *Almagest* III.5 are preserved in small pieces of paper sewn between fols. 180 and 181.

123 In the famous miniature of a school in Madrid Skylitzes (Biblioteca Nacional, Vitr. 26–2, fol. 134), students listen to the teacher while seated around a table that has fewer books than students, who must therefore share them. Byzantine schools could also share with some modest, modern schools the habit of keeping the books that students will use generation after generation. Byzantine wax-tablets were preserved only accidentally, but the extended use of the word *pinax*, *pinakes* in school contexts may plead in favour of considering them as common objects, especially at the elementary school, even if the word may also refer to parchment or paper quires.

124 On the restoration of Byzantine books, see Bianconi, *Cura et studio.*

125 As the famous Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 1291, fols. 1–2v; Canart et al., *Facsimili*, no. 8; Mogenet, "Les scolies astronomiques du Vat. gr. 1291." Or Paris, Bibliothèque Nationale de France, Par. gr. 2396, with Theon's commentary to the *Almagest*, whose fols. 1–2 display a table of the anomalies of the sun and the moon canons and tables, whose titles in fol. 1 were written by Gregoras' hand; on the manuscript, see Mondrain, "Maxime Planude, Nicéphore Grégoras," who is silent on the handwriting of these pages.

Biblioteca del Real Monasterio, X.IV.5,[126] Paris, Bibliothèque nationale de France, suppl. gr. 387 (a collection copied, and probably prepared, by a scholar at the beginning of the fourteenth century),[127] Vienna, Österreichische Nationalbibliothek, phil. gr. 65 (an elegant copy from the second quarter of the fifteenth century),[128] and Uppsala, Universitetsbibliothek, gr. 8 (from the late fifteenth century).[129]

### 4.1 *A Canon of Classical Handbooks*

When dealing with learning methods, the evidence preserved by the manuscripts has never been extensively analyzed in depth or even fully edited. The reason is that texts belong to a realm of the literature whose fragmentation and unspecified authorship make them less accessible. When a precise codex presents evidence of different contemporary hands correcting the text or developing problems in the margins, we are witnessing an excellent example of a "community of learning," a group of people meeting the challenge of struggling with the understanding of a scientific text.[130] Furthermore, especially in the Palaiologan period, it is not uncommon to find reference books or school texts copied by many scribes belonging to the same generation. If some of them are not really skilled scribes and produce irregular and clumsy pages of text, then in that case we are facing a schoolroom at work: the manuscript is considered a common project and any help is welcomed or even required. If the communal work seems to be organized by a hand that writes titles or makes comments and corrects the copy, then we have found the teacher who promoted the plan and probably provided the model.[131]

Alternatively, other manuscripts are the bedside books of a student who decided to gather in a single volume separate copies of texts that were considered basic reading for a general or complete training. In some cases, scientific

126 See Andrés, *Catálogo de los códices griegos*, vol. 2, p. 329. See chapter 3 of this volume.

127 Vogel, *Ein byzantinisches Rechenbuch.*

128 Hunger/Vogel, *Ein byzantinisches Rechenbuch*; Chalkou, *Το μαθηματικό περιεχόμενο.*

129 Searby, "A Collection of Mathematical Problems."

130 A famous example is the Euclid Bologna, Biblioteca dell'Archiginnasio, A-18 and A-19, a tenth-century manuscript annotated by Demetrios Kydones, Theodore Kabasilas, and other fourteenth century hands; see *Euclidis opera omnia*, ed. Heiberg/Menge, vol. 5, pp. xi, xxxiii–xxxiv; Acerbi/Pérez Martín, "Les études géométriques."

131 Vat. gr. 1087, copied by ten hands, apart from Nikephoros Gregoras, who annotated it, added diagrams and included his own texts, is an excellent example: see Menchelli, "Struttura e mani del Vat. gr. 1087"; the manuscript gathers Metochites' *Astronomike Stoicheiosis* with Theon's commentary to Ptolemy's *Syntax*, as well as a famous set of drawings of constellations.



FIGURE 2.1 The *Nymphe* or figure of Pythagoras' theorem

material is mixed with other kinds of texts. This happens in Bremen, Staats- und Universitätsbibliothek, b.23, which gathers together Sophocles, Aelius Aristides, Xenophon's *Cyropedy*, Demosthenes, etc. with Cleomedes and Symeon Seth's *Physical Synopsis.* The clumsy handwriting of the owner and main scribe of the manuscript, Isidoros, suggests that he was a young man eager to gather rhetorical models and elementary knowledge on natural science and astronomy.[132]

In other cases, scholars created "personal encyclopaedias" of scientific texts, such as the two-volume set that makes up Paris, Bibliothèque Nationale de France, gr. 2342 and Vatican, Biblioteca Apostolica Vaticana, gr. 198, and transcribed by Malachias during the 1360s and 1370s; in fact, they comprise "the largest mathematical encyclopaedia assembled during the Palaiologan period."[133] The reconstruction of the libraries of some Palaiologan scholars (or sometimes of the books to which they had access) allows us to identify other cases of scientific corpora, whose study shaped the vast learning of owners who worked on them solitarily. The pride of having acquired all this knowledge pervades their correspondence.

These kinds of books, even if not easily classifiable, help us single out the reference authors of the scientific disciplines, supplementing the evidence texts themselves give. Vitrac has written some skeptical pages about the school use of texts such as the *Elementa*: according to him, the high number of copies of this text does not necessarily guarantee its common use in the school room. It is possible to agree with him when he offers the explanation that annotated copies of ancient texts are more likely to belong to study circles than to the school environment,[134] but a higher level scientific school in Byzantium was not really very different from a "cercle érudit."

However, when Gregory II of Cyprus (*c*. 1241–1290) writes that George Akropolites explained Euclid and Nicomachus of Gerasa in his lessons,[135] he was referring to the very works of these authors, who in Byzantium had no epitomes or abridged versions that could replace them. Both of them are mentioned

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132 Pérez Martín, "The Scribe Isidoros."

133 See chapter 3 of this volume. Mondrain, "Traces et mémoire," pp. 5–7, Acerbi, "Byzantine Recensions," pp. 154–59, proving that Planudes is not the author of the recension of the scientific texts gathered in Par. gr. 2342. Another example is provided by John Chortasmenos, who gathered in three volumes (Vatican, Biblioteca Apostolica Vaticana, gr. 1059, Vatican, Biblioteca Apostolica Vaticana, Urb. gr. 80, Vienna, Österreichische Nationalbibliothek, suppl. gr. 75) a mix of copies and personal drafts of calculations, tables, etc.; see Canart/Prato, "Les recueils organisés par Jean Chortasmenos."

134 Vitrac, "Quand? Comment?," pp. 48–52.

135 See above n. 25.

by Blemmydes, who adds Diophantus to the list.[136] There is no doubt that both were the most common texts of geometry and arithmetic,[137] while Archimedes for the average Byzantine was the main character of some curious stories and not a school author. Some Byzantines may name Diophantus as a gate to mathematical wisdom,[138] but his *Arithmetike* was as on the verge of disappearance as Archimedes' treatises. Ptolemy, on the contrary, was omnipresent in the collective mind, although it is likely that not many went beyond his *Handy Tables*. But astronomy for a Byzantine was not only a Ptolemaic field of action: the extraordinary successful Aratos found his place here too and there were more texts dealing with specific aspects of the geometry of solids useful for astronomical studies.[139] Other authors seem to have simply filled in the boxes of scientific learning: Aristoxenus was the reference author for harmonics, and Heron for geodesy. Indeed, the canon of school texts seems to have developed and changed in the Palaiologan period: Cleomedes, *De cyclica theoria*, for example, was apparently recovered by Nikephoros Blemmydes as well as Diophantus by Maximos Planudes.

### 4.2 *Two Byzantine* Quadrivia

Famously, only two treatises conceived as *quadrivia* and written by individual authors (as opposed to multitext codices put together for the purposes of teaching the mathematical sciences) survive from the Byzantine period. The so-called Anonymus Heiberg[140] dated to the second half of the 1007[141] and the so-called *Quadrivium* composed by George Pachymeres during the early

136 Nikephoros Blemmydes, *Autobiographia*, 1.8 (Engl. transl. Munitiz, p. 47).

137 Metochites states that they were the only mathematical texts studied for a long time; see Bydén, *Theodore Metochites'* Stoicheiosis astronomike, p. 228.

138 Such as the Pseudo-Elias ed. Westerink, pp. 38–39: τῆς μὲν οὖν ἀριθμητικῆς προέστη ὁ Νικόμαχος, τῆς δὲ λογιστικῆς ὁ Διόφαντος· πάλιν τῆς μουσικῆς προέστησαν οἱ Πυθαγόρειοι, ⟨τῆς δὲ ἐνύλου μουσικῆς οἱ Ἀριστοξένιοι, καὶ τῆς μὲν γεωμετρίας Εὐκλείδης,⟩ τῆς δὲ γεωδαισίας Ἥρων, τῆς δὲ ἀστρονομίας Παῦλος καὶ τῆς σφαιρικῆς ὁ Θεοδόσιος, ἐν οἷς ἔχομεν τὴν τοῦ θεωρητικοῦ ὑποδιαίρεσιν.

139 Metochites studied on his own Apollonius of Perge and Serenus, among other authors; see Bydén, *Theodore Metochites'* Stoicheiosis astronomike, p. 228.

140 This reference name was coined by Taisbak, "The date of the Anonymus Heiberg," and established further by Ebbesen, *Commentators and Commentaries*, vol. 1, p. 262.

141 The text has been dated by Taisbak, "The date of the Anonymus Heiberg" to the period between September 1 and December 14, 1007. Katsiampoura, "The *Quadrivium* of 1008," p. 412 dates it incorrectly to 1008.

Palaiologan period.[142] Joseph Rhakendites (d. *c.* 1330)'s *Encyclopaedia* is a plagiarism of the Anonymus Heiberg.[143]

Both works represent what scholars identify as the foundation of the education in the mathematical sciences in Byzantium, namely the author's rendering of the relevant ancient and late antique Greek knowledge exemplified by the authorities of Nicomachus of Gerasa and Euclid for arithmetic and geometry, Ptolemy, Theon of Alexandria, and Cleomedes during the late Byzantine period for astronomy and possibly Ptolemy again for the section on music. Scholars have also paid attention to whether or not the Byzantine authors have added a sort of "Christianizing spin" onto the pre-Christian Greek material, as for instance in Katsiampoura's comparison of the authorial approaches of the anonymous eleventh-century scholar and Pachymeres.[144] Moreover, the two works are conceived today as coherent and completed units of knowledge in contrast to multitext codices transmitting similar material but lacking an authorizing and authoritative figure who might anchor them within a concrete socio-historical context within which they may be associated or not with the processes of teaching and learning the so-called four μαθήματα. Thus, the two Byzantine *quadrivia* fit well into our pre-existing idea of how late antique structures of education were translated and preserved during the Byzantine period. What has been problematic for contemporary scholarship is the fact that these are the only two such books Byzantium has left us and their uniqueness prevents us from confidently pronouncing them as the rule rather than the exception. Thus, it is worthwhile dedicating a section of the present chapter to a discussion of relevant aspects of both works, their context of preservation, the picture of the sciences they portray and the biases revealed by the ways they have been approached by current scholarship.

### 4.2.1 Anonymus Heiberg

In view of the latter, the case of the Anonymus Heiberg is particularly illuminating. It has been discussed primarily by two groups of scholars, namely the historians of philosophy (and specifically of logic) and the historians of science as each focussed on the part of the text that holds interest for their respective disciplines.[145] Both approaches are justifiable as the manuscript tradition shows that various parts of the Anonymus Heiberg had independent

142 Tannery/Stéphanou (eds.), *George Pachymeres, Quadrivium.*

143 See chapter 3 of this volume.

144 Katsiampoura, "The *Quadrivium* of 1008."

145 For discussions of the logical part of the Anonymus Heiberg, see Ebbesen, *Commentators and Commentaries*, vol. 1, pp. 262–65; Ierodiakonou, "Rediscovering Some Stoic Arguments"; Ierodiakonou, "The Hypothetical Syllogisms"; Barnes, "Syllogistic in the Anon.

circulation. For instance, we find the section on the four mathematical sciences circulating as a compendium on its own under the name of Michael Psellos, a certain Euthymios or a certain Gregory.[146]

Two aspects of the Anonymus Heiberg as preserved in the Heidelberg, Universitätsbibliothek, Palat. gr. 281 (Fig. 2.2) have been of particular importance to the students of Byzantine philosophy, namely the dating of the work and whether or not the section on logic and the remaining chapters dedicated to the four mathematical sciences form a single treatise. The two questions are related, as the dating of the Anonymus Heiberg is based on a date found in the section on astronomy. Thus, while there is no doubt that the latter was written during the second half of the 1007, if we read it separately from the preceding part on logic, it would have to be dated to before 1040 when the codex itself was executed, but not necessarily to 1007.

The work lacks a prooimion and consists of five chapters of unequal length, entitled *Comprehensive composition on philosophy*; *Hither, a concise account on numbers*; *Accurate overview of music*; *Such* (*i.e. accurate*) *overview of the principles of geometry* and *Comprehensible compilation on astronomy*.[147] It ought to be mentioned that there is no general title for the work as a whole. While we will not be examining here the syllogistic theory the Anonymus Heiberg expounds, it is important to consider what is meant by logic and philosophy and how they relate to the four mathematical sciences (see § 1). It has been pointed out that both in the case of the curriculum described in the *Life* of Saint John Psichaites (third quarter of the ninth century) and in that of the Anonymus Heiberg, philosophy is synonymous with logic.[148] Barnes, however, has been careful to propose a distinction, namely, that the φιλοσοφία referred to in the

Heiberg." For the discussion of the scientific aspects of the Anonymus Heiberg, see chiefly Katsiampoura, *Πρόσληψη, μετάδοση και λειτουργία*.

146 These are all much later manuscripts dating to the period between the fourteenth and the seventeenth centuries, such as for instance, Paris, Bibliothèque Nationale de France, gr. 1931, 2062, 2136, 2465, 3067; suppl. gr. 541 and 677 and Vatican, Biblioteca Apostolica Vaticana, gr. 111. Further investigation is needed into the identification of the author of the Anonymus Heiberg as Gregory Aneponymos which if established would render a much larger pool of manuscript evidence. The eight manuscripts listed above mostly preserve the main diagrams we find in Palat. Heidelb. gr. 281 but feature no scholia, with the exception of the Par. suppl. gr. 677 (fifteenth, seventeenth centuries).

147 Συνοπτικὸν σύνταγμα φιλοσοφίας; ἐνταῦθ' ἀριθμῶν συντομωτέρα φράσις; τῆς μουσικῆς σύνοψις ἠκριβωμένη; σύνοψις αὕτη γεωμετρίας λόγων; ἄθροισις εὐσύνοπτος ἀστρονομίας. For the critical edition, see *Anonymi logica et Quadrivium: cum scholiis antiquis*, ed. Heiberg.

148 Ebbesen, *Commentators and Commentaries*, vol. 1, p. 257; Barnes, "Syllogistic in the Anon. Heiberg," p. 98. The same reduction of philosophy to syllogistics can be found in the educational autobiography of Nikephoros Blemmydes from which we know that the only philosophy he learned seems to have been logic. Moreover, its study was divided in

first book's title is "presumably short for 'instrumental philosophy'; and instrumental philosophy is the philosophical study of the instrument of the sciences—in other words, it is logic."[149]

Further, Barnes notes that the section on logic presupposes no previous knowledge of the matter.[150] The same is remarked by Katsiampoura regarding the chapter on geometry that starts from the basic tenets of the discipline, thus suggesting that this is subject matter the students had not encountered previously.[151] The section on astronomy relies on Ptolemy's *Almagest*. Again, references are made to the source texts itself which prompted Katsiampoura to conclude that, as in the case of the references to Euclid's *Elements*, "the *Syntaxis Mathematica* and the *Handy Tables* were easily found and studied."[152]

The copy of the Anonymus Heiberg in the Palat. Heidelb. gr. 281[153] preserves a number of marginal notes, scholia and diagrams in addition to the main text of the treatise, but on the whole the layout leaves ample room in the outer margins. The fact that these have been left blank prompts us to question the use of this particular codex for personal teaching or learning. Fol. 85r is the one that contains the most extensive scholia in the entire Anonymus Heiberg. It is written in black ink by a hand different from that of the main copyist Nikolaos and accompanied by diagrams. Unlike all previous diagrams in the codex *Palatinus*, these do not illustrate the narrative, but develop its topic further by illustrating the 3:2 ratio by means of the sequence of numbers 27, 18, 12, and 8 and then, by proceeding to construct the cubes of sides 18 and 27. Notably, the astronomical section does not include any type of diagram or visual aid, whereas the most elaborate harmonic diagrams are placed at the end of the volume on fol. 181v, after a series of four brief texts on harmonics among which one finds a *Division of a Musical Canon* (fols. 174r–179v) by Theon of Smyrna.[154]

Having discussed the structure of the Anonymus Heiberg, its layout in Palat. Heidelb. gr. 281 and the diagrams and scholia that accompany it, we should

between the stage of the *Trivium* and what followed the study of the *Quadrivium*. For more on Blemmydes's education, see § 2.

149 Barnes, "Syllogistic in the Anon. Heiberg," pp. 98–99.

150 Barnes, "Syllogistic in the Anon. Heiberg," pp. 98–100.

151 Katsiampoura, "The *Quadrivium* of 1008," p. 416. See also Tihon, "Enseignement scientifique," p. 99, on whether the Anonymus Heiberg was intended as a handbook for students of secondary or higher level.

152 Katsiampoura, "The *Quadrivium* of 1008," p. 420.

153 For a recent codicological description of the codex, see Ronconi, *I manoscritti greci miscellanei*, p. 206.

154 Mathiesen, *Apollo's Lyre*, p. 413. For Mathiesen's description of the Palat. Heidelb. gr. 281, see Mathiesen, *Ancient Greek Music Theory*, pp. 30–33.

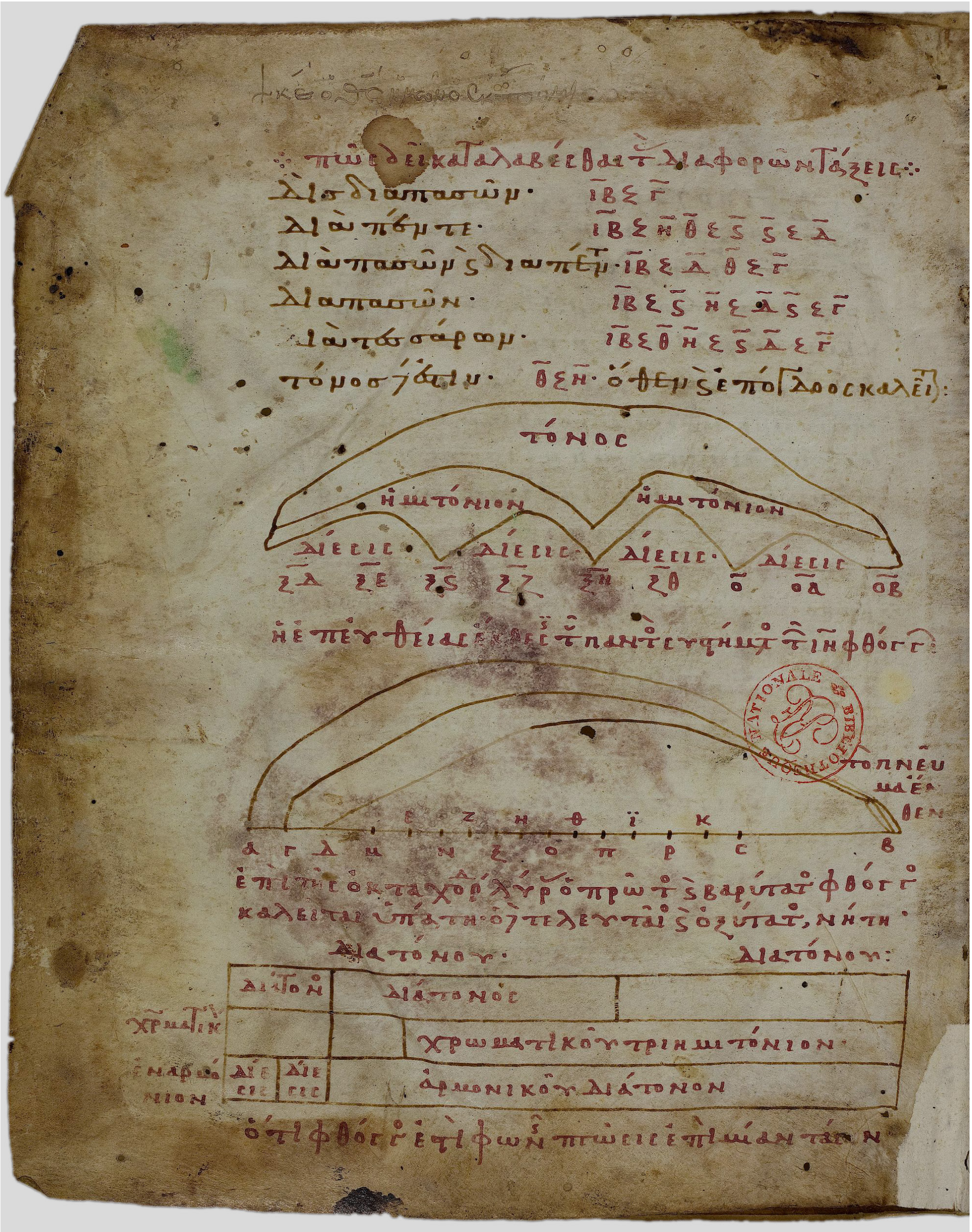



FIGURE 2.2 Elementary diagrams and definitions of intervals, tones, semitones, quartertones and pitches

return to an observation made earlier, namely that it is difficult to associate this eleventh-century copy of the text with a concrete educational environment such as the schoolroom or/and individual self-teaching. While the codex contains a number of works that can be discussed in the context of instruction in the mathematical sciences, the circumstance of its production, as far as we can deduce from the colophon on fol. 181, is rather that of a private commission carried out by the καλλιγράφος Nikolaos, a professional scribe associated with the imperial atelier, with the assistance and possibly upon the request of the high state functionary Romanos, *asekretis* and *krites* of Seleucia.[155]

### 4.2.2 Pachymeres

Having been a student at the school of George Akropolites in Constantinople, Pachymeres himself taught the four mathematical sciences in the Byzantine capital, as well as philosophy.[156] This is the first sense in which his *Quadrivium* is unique in the context of the extant Byzantine educational works: unlike the Anonymus Heiberg, Pachymeres' text is not only the expression of the single vision of an author known to us, but it can also be tied to his attested teaching activity. Equally important is the fact that Pachymeres' *Quadrivium* survives in fourteen manuscripts, the most important of which, Rome, Biblioteca Angelica, gr. 38, has also been identified as Pachymeres' autograph.[157] Thus, we have a privileged access into an arrangement of the material, both textual and diagrammatic, that exists in accordance with the author's views.

Thirdly, the textbook whose complete title reads *Σύνταγμα τῶν τεσσάρων μαθημάτων: ἀριθμητικῆς, μουσικῆς, γεωμετρίας καὶ ἀστρονομίας* (*Treatise on The Four Mathematical Sciences: Arithmetic, Music, Geometry, and Astronomy*) when compared with the Anonymus Heiberg, "is significantly different, in every aspect more complete, scholarly and epistemically superior."[158] While Pachymeres relied on a variety of sources in the preparation of the *Quadrivium* (Nicomachus, Diophantus and Euclid for arithmetic; Ptolemy and Porphyry for music; the *Elements* and, significantly, the *Optics* of Euclid for geometry; and Aratos, Archimedes, Aristotle, Cleomedes, Euclid, Ptolemy and Theon for astronomy), he demonstrated a noticeable degree of independence when dealing

155 Further discussion is offered by Ronconi, *I manoscritti greci miscellanei*, pp. 201–18.

156 On Pachymeres' teaching, see Golitsis, "Georges Pachymère," and especially 59, with the testimony of a letter sent to him by Constantine Akropolites where he categorizes Pachymeres' teaching according to different stages, from logic and physics to theoretical mathematics and theology (τὸ τῆς φιλοσοφίας μαθηματικόν τε καὶ θεολογικόν).

157 Harlfinger, *Die Textgeschichte*, p. 357, n. 3.

158 Megremi/Christianidis, "Theory of Ratios in Nicomachus' *Arithmetica*," p. 4. See also Katsiampoura, "The *Quadrivium* of 1008," p. 424.

with them.[159] For instance, Pachymeres offered arithmetical interpretations of geometrical propositions by Euclid and included seventeen theorems from Euclid's *Optics* in the book on geometry. Further, in the book of arithmetic he included a series of problems derived from Diophantus and showed considerable originality by combining them with material from Nicomachus.[160]

## 5 Fragmenting Knowledge

Byzantine scientific texts may reflect ways by which some scientific subjects, especially in the fields of the natural sciences and medicine, were explained, namely, through a process of fragmentation and condensation.[161] This made them more accessible and turned the transmitted knowledge into lists of names, classifications,[162] sets of questions and answers, groups of *zetemata* or *problemata*, or commentaries on specific parts of a text. In many of these minor genres of school texts, Byzantine production was embedded in a tradition going back to the ancient philosophical schools. For this reason, the raw and anonymous materials we find in manuscripts have to be studied carefully before being classified as 'ancient' or 'Byzantine.' Luckily enough, in some cases their attribution to a Byzantine teacher, be it partly or mostly traditional knowledge, provides us with a firm footing.

### 5.1 *Lists and Classifications*

In Byzantine learning, the drawing up of lists and schemes of concepts and words was a common tool occasionally attested to in books. As a matter of fact, it is not unusual to find in margins or blank spaces lists of islands, gulfs, wonders of the world, or winds corresponding to an elementary level of learning.[163] The lists could be in verse, such as Niketas of Heraklea's *Πόνημα* (*c.* 1050–after 1117), that included five *stichera* with geographical names.[164] Likewise, the concordance lists of ancient and Byzantine names of places edited by Diller

159 Megremi/Christianidis, "Theory of Ratios in Nicomachus' *Arithmetica*," p. 5.
160 Megremi/Christianidis, "Theory of Ratios in Nicomachus' *Arithmetica*," p. 5.
161 Horster/Reitz (eds.), *Condensing texts*, gathers several interesting contributions on those processes, but unfortunately without Byzantine case-studies. Cf. Papadoyannakis, "Instruction by Question and Answer," pp. 100–102; Zucker, "Qu'est-ce qu'épitomiser?"
162 See § 6.
163 They rather come up from the study of a literary text, especially Homeric poems; see Legras, "L'horizon géographique de la jeunesse grecque."
164 Cf. Schneider, "La poésie didactique à Byzance," pp. 392 and 420.

could provide useful guidance in locating ancient toponyms as well as in 'classicizing' Byzantine (sc. later to Slav invasions) toponyms in school compositions.[165]

In some disciplines closer to philosophy, lists play a part in an Aristotelian frame of reference that organizes knowledge through subdivisions (διαιρέσεις) (Fig. 2.3).[166] This is especially evident in medical teaching, where we may find extreme cases such as the division of health in a scale of grades called ὑγείας πλάτος;[167] or the lemmatizations made by Psellos' compendium of 122 medical terms (*Περὶ καινῶν ὀνομάτων τῶν ἐν νοσήμασιν*),[168] or the composition of dictionaries such as Stephanus of Byzantium's *Ἐθνικά*, or *Περὶ πόλεων*.[169] But it may also occur through systematic classifications, as in Psellos' *Πόνημα ἰατρικόν*, where the colour, consistency, and sediment of the urine are used to classify the symptoms of nephrological diseases.[170]

### 5.2 *Scientific Questions and Answers*

Learning through the process of questions and answers was perhaps the most common method at the Byzantine school,[171] a very noisy place because this way of memorizing knowledge involved not only the teacher's answers to questions asked by students (or vice versa), but also the way in which schoolmates interrogated each other in order to strengthen their understanding of a

165 Diller, "Byzantine Lists."

166 Duffy, "Byzantine Medicine," 22.

167 The diagram, inspired by Galen, appears in some manuscripts related to the medical teaching of John Argyropoulos (d. 1487) at Petra; see Pietrobelli, "Variation autour du Thessalonicensis Vlatadon 14," pp. 105–8, Ieraci Bio, "Giovanni Argiropulo," pp. 794–96.

168 The work (CET.DISC:17 Moore, *Iter Psellianum*, p. 421) is based on Paul of Aegina; cf. Hohlweg, "Medizinischer 'Enzyklopädismus,'" p. 48.

169 The educational use of this text was enhanced by Aldus Manutius (1449/52–1515) in his editio princeps of 1502: "[Stephanus' *De civitatibus*] is a text of great value and absolutely essential for students of the humanities in their reading of history and poetry, in which they are regularly occupied. He gives in elegant form and in alphabetical order information about almost all the cities named in those historians and poets […]."; see Wilson, *Aldus Manutius*, p. 91.

170 Moore, *Iter Psellianum*, p. 486 (POE.9); cf. Hohlweg, "Medizinischer 'Enzyklopädismus,'" p. 43.

171 On the different names of this genre of "questions-and-answers" and the nature of the texts we label so, see the Preface by Volgers in Volgers/Zamagni, *Erotapokriseis*; cf. the interesting approach of Papadoyannakis, "Instruction by Question and Answer," to the subject, where he takes an approach from the inside of "a culture of conversation, debate, and disputation."

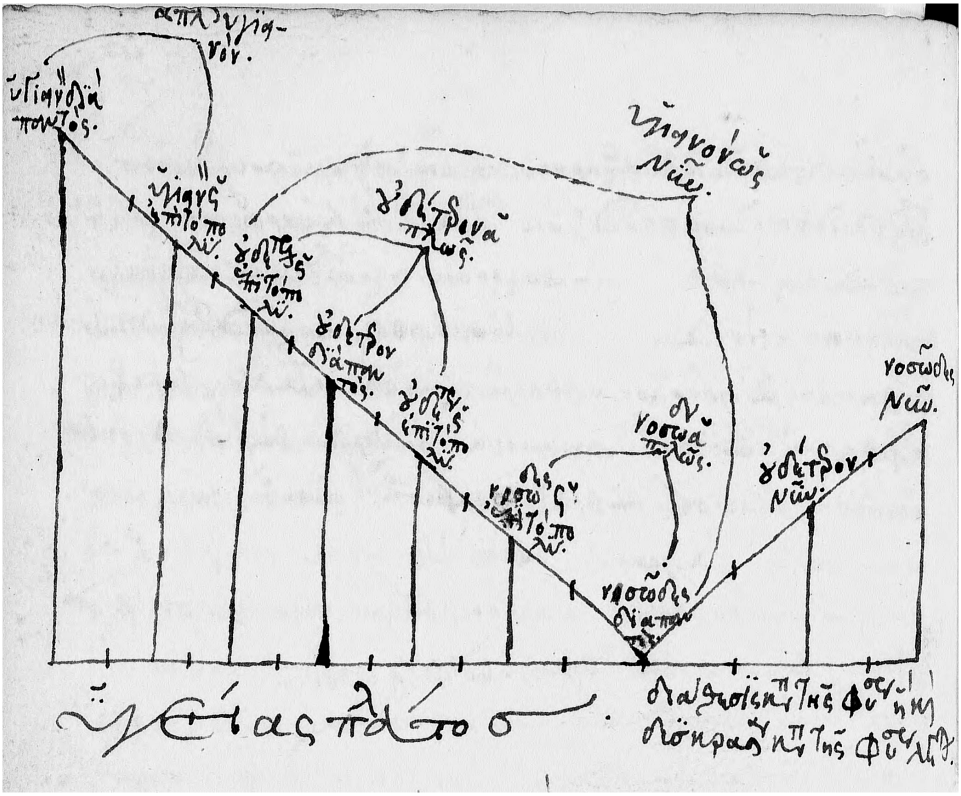


FIGURE 2.3 “Health’s length”: a diagram to assess levels of disease

syllabus.[172] The echo of their voices lives on in some stylistic elements defining the genre of the so-called *Erotapokriseis* that “imitate the actual performance of the teacher,” as Papadoyannakis pointed out.[173] The collections of questions and answers deal basically with theological notions, but in the sixth century the Pseudo-Kaisarios’ *Πεύσεις* (‘inquiries’) were the first to include questions

172 Nikolaos Mesarites, *Ekphrasis of the Church of the Holy Apostles* (written between 1198 and 1203), § 42.1 (ed. Downey, “Nikolaos Mesarites,” pp. 916–17, transl. *ibidem*, p. 894); Guilland, “La vie,” p. 80; Flusin, “Un lettré byzantin,” p. 76. Cf. Schamp, “Du verbe au Verbe,” p. 4, on Photios’ testimony. Psellos, or. 21, lines 77–79 (*Oratoria minora* ed. Littlewood, p. 78), states that students pay more attention to his words when he answers questions: ἂν δ’ ἐπιζυγώσω τὰς θύρας συρρέουσιν, ἂν ἐφέξω τὰς ἀποκρίσεις, τότε ὑμῖν περισπούδαστος ὁ λόγος γενήσεται.

173 Papadoyannakis, “Instruction by Question and Answer,” pp. 94–98.

about nature, the earth, or the cosmos.[174] Although the chapters completely miss the point and deviate from the Alexandrian tradition, the spreading of this and other ductile collections in poorly educated circles makes them even more interesting in assessing the level of knowledge outside the learned environments.

The mix of theological and scientific questions continued in Byzantium thanks to Michael Psellos' *De omnifaria doctrina*, a collection of theological and philosophical common notions preserved in approximately 150 copies.[175] Symeon Seth's *Physical synopsis* (in some manuscripts the title is *Ἐπιλύσεις σύντομοι φυσικῶν ζητημάτων*) apparently follows the same doxographical tradition, but its chapters, introduced by περί, are convincing and substantial expositions of geographical, physical, and astronomical questions.

Some medical texts reflecting methods of exposition of diseases share the question/answer scheme.[176] The most substantial collection preserved is attributed to a Paulus Nicenus. It gathers 133 questions into two groups: the questions of the first group ask for a definition and description of the disease; the second group describes how they are cured.[177] Medicine and natural sciences are also the fields explored by some sets of *problemata* that involve causal questions in what were presumably school settings, hence their name, προβλήματα ἐγκύκλια.[178] These exercises, in fact, use dialectical training to manipulate concepts of physics and medicine.[179]

174 Ed. Riedinger, whose title *Erotapokriseis*, apparently does not belong to the manuscript tradition; see Rey, "Les *Erotapokriseis* dans le monde byzantin," p. 168; Papadoyannakis, "Instruction by Question and Answer," pp. 96–97.

175 Michael Psellos, *De omnifaria doctrina*, ed. Westerink; and cf. his *Other solutions* (PHI.28, Moore, *Iter Psellianum*, p. 255). On the meteorological chapters, see chapter 5 in the present volume and Telelis, "Οι λόγιοι του 11ου αιώνα," pp. 429–30, 432–34, and Papadoyannakis, "Instruction by Question and Answer," pp. 100–101.

176 Leith, "Question-Types in Medical Catechisms," proposed to link the medical *erotapokriseis* founded in papyri to Aristotle's dialectical method. Medical catechisms are common from the second century CE: see Ieraci Bio, "L' ἐρωταπόκρισις nella letteratura medica," as well as Marganne,"La transmission du savoir médical," pp. 271–73. For examples in the Arabic world, see Pormann, "Medical Education In Late Antiquity," pp. 431–34, on Hunain's *Questions on the Epidemics.*

177 The editor, Ieraci Bio, *Paolo di Nicea, Manuale medico*, dates the collection to the seventh-ninth centuries.

178 Blair, "The *Problemata* as a Natural Philosophical Genre," pp. 174–75. On the Christian tradition of the physical problems, see Jouanna/Guardasole, *Problèmes hippocratiques*.

179 Ed. *Σύνοψις τῶν φυσικῶν*, ed. Delatte, *Anecdota Atheniensia*, vol. 2, pp. 17–89.

### 5.3 *Commentaries*

Commentaries on ancient texts were widespread in Byzantium, and we associate their reading with the school room,[180] but in the scientific field extensive commentaries were rare.[181] Eustathios of Thessalonike names his commentary on Dionysius Periegetes' *Parekbolai*, *sc*. excursus or digressions based on the ancient text, from which the teacher chose the subjects to develop, although in this case the commentary was a systematic and detailed one. A more uneven commentary is John Pediasimos' *Ἐξηγήσεις μερικαί*[182] to Cleomedes' *De cyclica theoria*, that divides the text under discussion into units that the teacher considered demanded further explanation or supplementary information from other authors who shape the "reference library" of the author and his students: Euclid, Theodosius of Bithynia, Ptolemy, or Aristotle. Another text by Pediasimos, a group of explanatory notes to the theory of intervals, introduces itself as *Ἐπιστασίαι μερικαὶ εἴς τινα τῆς ἀριθμητικῆς σαφηνείας δεόμενα.*[183] More often, the works of Pediasimos and other Palaiologan scholars on astronomical or mathematical texts were merely focussed on solving difficulties related to a defective transmission or the difficulty of the text, without any pretence of tackling the entire reference work.[184]

## 6 Outlining Knowledge

The use of drawings, figures, and diagrams was an essential part of learning in some scientific fields,[185] although sources give scarce evidence of it.[186] As a

180 On the "explanatory tactics" of late antique commentaries on Aristotle's *Meteorologica*, Taub, *Science Writing*, pp. 86–110.

181 As opposed to Aristotelian commentaries, a genre that survived in Byzantium. Stephanus Alexandrinus wrote a commentary to the most elementary text of the Ptolemaic astronomy, the *Handy Tables;* see Pingree, "The Teaching" and Lempire's partial edition of Stephanus. The commentary on Aristotle's *Physics* attributed to Psellos (PHI.27, Moore, *Iter Psellianum*, pp. 252–55) was composed by George Pachymeres; see Golitsis, "Un commentaire perpétuel."

182 Caballero Sánchez, *El Comentario de Juan Pediásimo*, p. xxiv.

183 Ed. with French transl. by Vincent.

184 This is common thread to other scholars working on mathematics; see Acerbi, "Types, Function, and Organization."

185 In 2018, a Dumbarton Oaks Symposium "The Diagram Paradigm: Byzantium, the Islamic World, and the Latin West" was organized. It is the first and only initiative on the topic.

186 But see Maximos Holobolos' testimony on the students' activity at the imperial school (or. 3, Treu p. 96): young people train themselves in logic, physics, ethics, and politics (lines 23–30). "Another one takes pleasure in determining the quantity, enumerates the different modes of ratios, deductions and proportions, and reckons a soloist or choral

result we are limited by the testimonies manuscripts preserved. Illuminated non-liturgical manuscripts are uncommon, and scientific books with illustrations are not necessarily related to the school room. However, in a very original and lavishly illuminated medical book, Florence, Biblioteca Medicea Laurenziana, Plut. 74.7, known as the chirurgical collection of Niketas, an epigram in fol. 7v suggests that the illustrations had not only professional but also teaching purposes.[187] Likewise, the images in some collections of Hippiatric texts can be understood as an aid to memory,[188] and a page of the famous Vienna Dioscorides (Vienna, Österreichische Nationalbibliothek, med. gr. 1, fol. 483v) displays grid cells with bird species that recall the traditional pedagogical sheets that hang on the walls of the school room.[189] Herbals too may have been used for reference or as a teaching tool.[190] The drawings of the constellations in Vat. gr. 1087, whose captions were added by the book owner Nikephoros Gregoras, provide a beautiful surprise for the student of scholarly Byzantine books.[191]

School was not however the natural place for the display of expensive images. Instead, average images were employed that could be almost effortlessly created with simple instruments and that could be included in a single sheet or in the margin of a text either to complete it or to contribute to its understanding (Fig. 2.4). The relationship between text and figure in mathematical texts has been explored recently with great thoroughness; what, however, interests us here is not the evaluation or reconstruction of the diagrams and figures created by ancient mathematicians, but, more modestly, the use Byzantine teachers made of lettered diagrams that helped students to understand the planetary positions or to solve geometrical problems.[192] It is unnecessary perhaps to state that scribes and scholars concerned themselves with the transmission of the figures accompanying ancient astronomical and mathematical texts. As might be expected, a teacher such as Pediasimos included figures in

unit. One student speculates about triangles, another about parallelograms; *one of them delineates a figure, the other inscribes the letters*—and another one pays heed to a different lesson." (lines 30–35: περὶ τὸ διωρισμένον ἕτερος ἐνασμενίζει ποσὸν καὶ τρόπους λόγων καὶ ὑπολόγων καὶ ἀναλογιῶν ἐκζητεῖ καὶ μονάδα μονῳδουμένην καὶ πολυῳδουμένην καταριθμεῖ· καὶ ὁ μὲν περὶ τῶν τριγώνων, ὁ δὲ περὶ τῶν παραλληλογράμμων φιλοσοφεῖ· **καὶ ὁ μὲν περιγράφει, ὁ δ' ἐγγράφει τὸ σχῆμα·** καὶ κατ' ἄλλο ἄλλος τι τῶν μαθημάτων φιλοπονεῖ.).

187 It is a tenth-century manuscript that displays illustrations of bandages and cures for traumatisms; see Bernabò (ed.), *La collezione.*

188 Lazaris, "Learning and memorising hippiatric knowledge," pp. 281–88.

189 Lazaris, "L'image paradigmatique," p. 146.

190 Collins, *Medieval Herbals*, pp. 27, 68–69, 302, 307; Gundert, "Die *Tabulae Vindobonenses*."

191 Guidetti/Santoni (eds.), *Antiche stelle a Bisanzio;* on the manuscript, see p. 57 and n. 131

192 See Jones, "Mathematics, Science, and Medicine in the Papyri," p. 341.

his commentary to Cleomedes.[193] Likewise, Isaak Argyros, when he adds at the end of his copy of Ptolemy's *Geography* his own explanation of the first Ptolemaic projection of the earth (Εἰς τὸ πρῶτον σχῆμα τῆς ἐν ἐπιπέδῳ καταγραφῆς τῶν οἰκήσεων, cf. Ptol. *Geogr.* I.24) in Vat. gr. 176, fols. 26v–27, first he adds the figure of the projection and then he copies his scholion around it.[194] John Chortasmenos, for his part, when he starts working on Ptolemy's maps, designs a draft with the contour of Ireland and Great Britain before abandoning the task.[195]

Probably, Chortasmenos had no access to the Ptolemaic maps and was trying to draw them following the geographer's instructions, but some illustrations are so simple that they did not need to be a reproduction of what was found in the model, since the text could evoke them in the scribe's or reader's mind, who then reproduced them easily in the book. They are, for example, the elementary figures or *schemata* of a treatise on geodesy[196] or of a geographical text that uses geometrical figures or common objects to evoke the shape of a peninsula or a mountain.[197] In a few manuscripts of Aristotle's *Meteorologica* we also find some figures that fulfill the role of scholia: a hydrographic map of the oikoumene (with rivers, seas and mountain chains: *Met.* I.13) and a rose of winds (*Met.* II.6).[198] An Oxford manuscript with an anonymous treatise on the

193 Caballero Sánchez, *El comentario de Juan Pediásimo*.

194 See Laue/Makris, "Isaak Argyros' Abhandlung"; Tsiotras, *Ἡ ἐξηγητικὴ παράδοση*, pp. 428–32, with the edition of the scholion.

195 Canart/Prato, "Les recueils," p. 134; these drafts are in Vat. Urb. gr. 80, fols. 5–6, 11v, 12v; cf. Tsiotras, *Ἡ ἐξηγητικὴ παράδοση*, pp. 156–93, esp. 166–67; Tsiotras thinks that Chortasmenos had a model for the maps.

196 The basic elements of metrological treatises or collections of measuring problems combine the verbal presentation and the figure of particular problems of measuring of areas, see the editions of geometrical texts gathered by Lefort et al., *Géométries du fisc byzantin*. Pediasimos' *Σύνοψις μετρήσεως καὶ μερισμοῦ γῆς* (ed. pp. 366–67) criticizes the trivialization of the geodesy, whose teachers have corrupted the figures, ignoring the simple forms "and expounding the names of the complex forms in a non-geometrical and barbarian manner, calling "sword" the isosceles triangle and "shoe" the composite form of a parallelogram with a trapezium, but also teaching the lines, angles and surface measuring in a barbarian and ignorant manner, as befits savage people." For the geometrical figures usually accompanying these geodesy handbooks, see Fig. 2.4 Par. gr. 2373, fol. 107v.

197 Heldelberg, Universitätsbibliothek, Palat. gr. 398 and other Strabo's manuscripts frequently show that kind of figure.

198 The role of diagrams in Aristotle's *Meteorologica* and its commentaries is studied by Taub, *Science Writing*, pp. 100–10, who does not know of the existence of these illustrations in Vienna, Österreichische Nationalbibliothek, phil. gr. 100 and Salamanca, Biblioteca General de la Universidad, Salm. 2747. Cf. Harlfinger, *Die Wiedergeburt*, pp. 33–41 and Prapa, "Diagramme in der Handschriftentradition."



FIGURE 2.4 Lines and elementary geometrical figures

astrolabe, Oxford, Bodleian Library, Cromwell 12 (p. 215), has a rare design of a *rete*, the movable part of an astrolabe.[199] The manuscript Vatican, Biblioteca Apostolica Vaticana, Barb. gr. 4 (beginning of the fourteenth century), fol. 172, the earliest version of a text known as Nikolaos Rhabdas' *Letter*[200] has at the beginning of an arithmetical introduction (*Παράδοσις σύντομος καὶ σαφεστάτη τῆς ψηφηφορικῆς ἐπιστήμης*, fols. 171r–186v), the contemporary drawing of a hand. It is an aid for learning the method of representing numbers on the fingers of the hands: naming the fingers of the left hand, it serves as an adequate starting point for the student.[201]

## 7 Other Pedagogical Strategies

### 7.1 *Solving Mathematical Problems and Playing with Numbers*

A very important chapter on scientific learning in Byzantium concerns the problems that helped the student to learn reckoning (λογιστική, the theory concerned with numerable objects) and arithmetic (ἀριθμητική, the theory concerned with the property of numbers).[202] Logistic, while not traditionally included in the τετρακτύς, might, in fact, be a discipline better studied and of greater importance for the Byzantine educational contexts than the four higher mathematical sciences. Recently, Christianidis has proposed to enlarge our understanding of what was encompassed by Greek logistic including the treatment of the indeterminate problems of the first as well as of higher degrees, which means re-evaluating the work done by Byzantines on Diophantus.[203] As pointed out by Acerbi, solving Diophantine problems is the way a student gets acquainted with Diophantus.[204] For instance, as witnessed by Acerbi's analysis

199 Tihon, "Traités byzantins sur l'astrolabe," p. 338.

200 Tannery, "Notice sur les deux lettres arithmétiques de Nicolas Rhabdas" and Acerbi/Manolova/Pérez Martín, "The Source of Nicholas Rhabdas' *Letter to Khatzykes*."

201 On the use of fingers in reckoning, see Nikolaos Mesarites, *Ekphrasis of the Church of the Holy Apostles*, § 10.1: "Going on not much further you will see those who are busy with the art of reckoning. How do they close their fingers so continuously and as constantly open them, quickly curling them next to each other and even more quickly sending them off again, and learning, so to speak, the art of dancing with their hands and fearing the rod." (transl. Downey, "Nikolaos Mesarites," p. 866).

202 Already in 1886, Tannery, *Mémoires Scientifiques*, vol. 4, p. 61, emphasized the distinction between logistic and arithmetic whose origins he drew from Plato, the murky boundary between the two and the fact that logistic seems to have had a more prominent standing at given periods in the history of Greek mathematics. Cf. Fowler, *The Mathematics of Plato's Academy*, pp. 234–40, 268–76.

203 Christianidis, "On the History of Indeterminate Problems."

204 Acerbi, "Ones," p. 708: "[…] the Arithmetica presents a host of clever tricks and specific manipulations, which a student gets acquainted with by simply doing Diophantine problems."

of John Chortasmenos' interlinear annotations in the copy of Diophantus preserved in Matrit. 4678, the latter illustrates Chortasmenos' learning of Diophantine arithmetic via problem solution.[205] In addition to learning through solving already formulated problems, we have examples of scholars amending the classical texts by introducing problems of their own design. One such instance is Nikephoros Gregoras' addition to Book X of Euclid's *Elements*, into which he inserted an additional mathematical problem concerning the construction of a parallelogram published under the title of *Νικηφόρου τοῦ Γρηγορᾶ πρόβλημα*.[206]

We have already mentioned some elementary collections of problems of reckoning. The exercises they employ illustrate methods for converting measures or calculating areas or volumes, but do not offer procedural explanations as to why they are solved in that way.[207] The student is supposed to repeat the problems time and again to assimilate the patterns that will later be applied to different data. Indeed, persistent repetition of problems and concepts was a basic tool for acquiring new knowledge.[208] As Duffy has written, in medical commentaries from the sixth and seventh century in Alexandria repetition was an evident strategy to inculcate the precepts of the discipline.[209] Philoponus' explanations in his treatise on the astrolabe avoided geometrical procedures in order to not alienate the student,[210] and as Theon, the author of two commentaries on Ptolemy's *Handy Tables*, wrote,[211] the teaching of basic astronomical notions was often articulated through tables that did not require the comprehension of geometrical procedures.

Arithmetical problems aim at solving an unknown, i.e. at finding the number that fulfils the conditions specified in formulating the problem,[212] which

205 Acerbi, "Why John Chortasmenos Sent Diophantus to the Devil."

206 See *Euclidis Opera omnia*, vol. 5.2, *Scholia in libros VI–XIII cum appendicibus*, ed. Heiberg/Stamatis, pp. 349–50.

207 Jones, "Mathematics, Science, and Medicine in the Papyri," p. 341.

208 See Nikolaos Mesarites, *Ekphrasis of the Church of the Holy Apostles*, § 8.2: "others again, who surpass these in years and learning, carrying writing-tablets in their hands, rehearse problems completely from the beginning, some of which they gather wholly from the material which they have in their hands, others of which they obtain elsewhere, throwing the younger students into confusion and putting them at a loss" (transl. Downey, "Nikolaos Mesarites," p. 866).

209 Duffy, "Byzantine Medicine," p. 22.

210 Turner, *Mathematical instruments*, p. 59; cf. John Philoponus, *De usu astrolabii*, ed. Jarry, p. 3 lines 12–13 of the προοίμιον.

211 See Tihon, "L'astronomie byzantine," p. 608.

212 See Acerbi, "Ones"; Acerbi, "I problemi aritmetici."

means that they are not very different from arithmetical riddles.[213] The difference might be found in the formulation itself, namely, we should consider it as an arithmetical problem if it was in plain prose,[214] while a problem in verse would be a riddle, since poetry gives to the proposition the graceful and amusing manner demanded by a riddle. However, even the brainiest text, such as Diophantus' *Arithmetica*, may include an epigram formulating a problem.[215] Quite a few epigrams gathered in Book 14 of the *Anthologia Palatina* are arithmetical problems,[216] but other problems are preserved separately. Lampros edited Vienna, Österreichische Nationalbibliothek, theol. gr. 203 an arithmetical epigram attributed to the emperor Michael VIII.[217] For its part, a Mount-Athos manuscript, Monastery of Dionysiou 347, preserves some riddles in iambi and other meters composed by Isaak Argyros.

As is well known, in Greek antiquity poetry was employed as a common vehicle for knowledge, and as a way of conveying science as conceived from Homer and Hesiod to Aratos, Geminus, and Dionysius Periegetes. In Byzantium, some authors cultivated this genre; we have already mentioned Niketas of Heraklea's and Psellus' *Ponemata*, but we may add here two more poems composed by the *hypatos*, namely, on epilepsy and on the Roman calendar.[218]

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213 Cf. Nikolaos Mesarites, *Ekphrasis of the Church of the Holy Apostles*, § 8.3: "Still others, those who have achieved the higher and more complete stages, weave webs of phrases and transform the written sense into riddles, saying one thing with their tongues, but hiding something else in their minds." (transl. Downey, "Nicholas Mesarites," p. 866) This is probably about arithmetical riddles, since the text had just mentioned the problems some students rehearse.

214 Such as the brain teaser published by Spingou, "Byzantine game or a problem from Fibonacci's *Liber Abaci*?"

215 See Acerbi, "Ones."

216 A coherent group (epigrams 116–147) is attributed to "Metrodorus" (ed. Beckby, *Anthologia graeca*, vol. 4, pp. 228–47), but Book 14 displays other arithmetical problems intertwined with oracles; cf. Tannery, "Sur les épigrammes arithmétiques" (repr. in *Mémoires scientifiques*, vol. 2, pp. 442–46). Curiously, among the most preferred numerous objects in the problems of logistic we find the apples and the wreath. On the configuration of the *Anthologia Palatina*, see Cameron, *The Greek Anthology*, pp. 108–16 and 300–307; the collection was compiled shortly after 944 using an earlier epigram anthology produced by Constantine Cephalas during the last decade of the ninth century. Cephalas was in fact teaching at the school of the New Church and according to Lauxtermann, *Byzantine Poetry*, p. 86, the style of the proemia in some of the epigrams "leave no doubt that the anthology of Cephalas came into existence in the context of the Byzantine educational system."

217 Lampros, "Τρία βυζαντινὰ αἰνίγματα."

218 POE.11 (Moore, *Iter Psellianum*, p. 488, ed. Westerink pp. 234–35) and POE.18 (Moore, *Iter Psellianum*, p. 493, ed. Westerink pp. 252–54).

The different manuscripts ascribe to Photios, Blemmydes, and Planudes a poem on the diseases diagnosed through the urine.[219]

### 7.2 *Numerical Tables*

Numerical tables were extensively used in both the teaching and practice of arithmetic, and their use was especially necessary because of the non-positional system of Greek numerals, which hindered elementary operations.[220] Another challenge was the way fractions were expressed: their notation required any fraction to be broken down into the sum of a series of fractions such as 1/2, 2/3, 1/4 etc. (ex. 3/5 = 1/2 + 1/10), and tables were made that listed the results of the division.

### 7.3 *Scientific Devices*

Any mention of the use of instruments in learning is rare.[221] They may, however, have been common, from the simplest dividers used to draw the geometrical *diagrammata* up to the most sophisticated tools such as the parallactic instrument (παραλλακτικὸν ὄργανον, for determining a parallax or distorted view) represented in detail in the MS Florence, Biblioteca Medicea Laurenziana, Plut. 28.18, fol. 279v, a ninth-century codex with Theon of Alexandria's and Pappos' commentaries on Ptolemy's *Almagest*.[222] The well-known astrolabe, the basic instrument for astronomical measurements, has been proved to have been used in astronomical teaching.[223] Manuel Holobolos (*c.* 1245–1310/14) provides a neat school context for the use of armillary spheres,[224]

219 Tessari, *Studi su Fozio innografo*, pp. 29–30.

220 Jones, "Mathematics, Science, and Medicine in the Papyri," p. 340, counts up 20 papyri with that kind of tables.

221 Indeed, the only mention of an abacus we have found is in a translation from the Arabic, ed. Jones, *An Eleventh-Century Manual*. There are no mentions of another device, the παράπηγμα, a monthly calendar usually inscribed on stone.

222 See Lazaris, "Scientific, Medical and Technical Manuscripts," pp. 67–68 and Fig. 15.

223 Lewis, *Surveying instruments*, on the dioptra, the astrolabe, and other instruments adapted to ancient engineering. John Philoponus' treatise *De usu astrolabii* had a very didactic approach; see ed. Jarry, pp. liii–iv. Also Geminos used astronomical instruments as tools for instruction more than as instruments of observation; see Evans/Berggren, *Geminos's Introduction*, pp. 27–42. Philoponus' work served as inspiration for other similar treatises in the fourteenth century; see Tihon, "Traités byzantins" and most recently Tihon, "Astronomy," pp. 194–95; apparently, however, only one Byzantine astrolabe, the so-called Brescia astrolabe, survives today: it dates from 1062 and manifests its Persian inspiration; see Turner, *Mathematical instruments*, p. 11.

224 *Manuelis Holoboli Orationes*, Or. 1, pp. 49–50 Treu. On Gregoras' chambers, full of spheres, books and designs (σφαιρῶν δὲ ἐμπίπλησι τὴν οἰκίαν καὶ πάντα βιβλίων γέμει καὶ διαγραμμάτων), see Garzya, "Un opuscule inédit de Nicolas Cabasilas," 530, lines 153–155.

whose importance in the understanding of the movements of the planets and the stars is beyond any doubt.[225] Apart from that, the rare examples of Byzantine astronomical instruments that have been preserved are five sun-dials[226] and an astrolabe from 1062 showing Arab influence.[227]

Medical instruments were also improved in Byzantium.[228] John Zacharias Aktouarios, born and active in Constantinople as a practicing physician,[229] was the author of three medical treatises. His uroscopy treatise *On Urines* (*Περὶ οὔρων*) records and explains the design and diagnostic use of the urine vial he invented. The vial is divided into eleven sections and its purpose is to identify various sediments in a urine sample, in order to arrive at a diagnosis of the patient's illness.[230]

In an extra-curricular discipline such as geography, the use of maps was more common than expected, even if very few people could afford to have a copy of Ptolemy's 'diagrams.' Psellos' *Περὶ τοῦ γεωγραφικοῦ πίνακος*, explains how to draw a map of the oikoumene following the description given by Strabo and summarized by the hypatos. In Eustathios' *Parekbolai* to Dionysius Periegetes maps and their design are by no means exceptional. Holobolos mentions the small διφθέρα (parchment) that can host a map of the earth.[231]

## 7.4 *Predictions and Experiments*

The social recognition that science gave in Byzantium is made manifest through both the most common or the most prestigious applications of the

225 For the sphere as a complement for Aratos' reading, see Turner, *Mathematical instruments*, p. 62.

226 Turner, *Mathematical instruments*, p. 61.

227 See chapter 6 of this volume.

228 Bliquez, "Two lists of Greek surgical instruments," p. 191–193, on the lists of surgical instruments found in Paris, Bibliothèque nationale de France, lat. 11219 and Florence, Biblioteca Medicea Laurenziana, Plut. 74.2.

229 *PLP* 6489. For John Aktouarios and his *On Urines*, see Bouras-Vallianatos, "Case Histories in Late Byzantium."

230 Diagrammatic depictions of Aktouarios' vial and its fragmentation according to sections accompany the relevant portions of the treatise in the manuscripts. See, for instance, the diagram executed in red ink in the outer margin of p. 398 of Warsaw, Biblioteka Narodowa, Boz. Cim. 155 (*c.* 1390–1400). This earlier depiction renders a more 'realistic' image compared to the extremely schematic diagram inserted in the outer margin of the fifteenth-century Florence, Biblioteca Medicea Laurenziana, Plut. 74.13, fol. 108v. Note that the late fourteenth-century diagram indicates a difference in volume between various sections of the vial, whereas the later Florentine manuscript depicts all eleven sections as equal in size. For more on the use of Aktouarios' urine vial, see Bouras-Vallianatos, "Contextualizing the Art of Healing," pp. 111–12.

231 See chapter 7 of this volume.

notions acquired at school. Even if technical knowledge required for building or marine navigation will stay in the shade forever, in other cases their commonplace character is evident: the Paschal computus is one of them,[232] as manifested by outnumbered tables that calculate Easter and that for us have the added value of their dates; the fiscal measurement of land or the casting of horoscopes are other examples.

But doubtless the most prestigious calculations were the explanations or predictions of eclipses, that often were followed by controversy,[233] and the public discussions on this and other natural phaenomena such as earthquakes. Michael Attaleiates (*c.* 1022–1080) in his *History* records public discussions on earthquakes after the Macedonian coast was badly damaged in 1063.[234] The eclipse in June 1239 prompted a discussion in the court of Nicaea between George Akropolites and the *aktouarios* Nikolaos—the empress Eirene herself asked for an explanation from Akropolites.[235] But the first who felt confident enough to predict an eclipse were Nikolaos Rhabdas in 1321[236] and Nikephoros Gregoras in 1330,[237] who apparently challenged Barlaam to do so with eclipses in 1333 and 1337.[238]

In his little-known essay on lunar theory, Demetrios Triklinios (fl. 1308–*c.* 1330) described how to conduct an experiment involving the use of a mirror whose size, position, and movement were supposed to facilitate the observation of the moon.[239] In all cases, Triklinios suggests using a mirror in the context of performing observations of the human-shaped dark figure apparent on the lunar surface. Initially, Triklinios states that he himself gained knowledge of the orientation of the dark figure during the period when the moon is located below the horizon:[240]

232 And a novelty of the Christian era, as recalls Turner, *Mathematical instruments*, p. 63.

233 On the eclipses as forerunners of misfortunes, see chapter 13 of this volume.

234 Michael Attaleiates, *Historia*, pp. 88–89 Bekker.

235 George Akropolites, *Historia*, § 39 (transl. Macrides pp. 210–11 and see her n.12).

236 Riehle, "Epistolographie und Astronomie."

237 Nikephoros Gregoras, *Calcul de l'Éclipse*, ed. Mogenet et al. Gregoras mentions in several letters his predictions and he even purports to work with his students in order to predict eclipses; see Cuomo, "Nicephorus Gregoras, Barlaam Calaber," pp. 194–96.

238 Barlaam Calaber, *De eclipse solis*, ed. Mogenet/Tihon.

239 Wasserstein, "An Unpublished Treatise."

240 The diagrams accompanying Triklinios' treatise are published in Wasserstein, "An Unpublished Treatise by Demetrios Triklinios" and discussed briefly in Lazaris, "Scientific, Medical and Technical Manuscripts," p. 69, Fig. 16.

> […] when ⟨the moon⟩ is below the earth and is traversing the parts below, the head of this figure is downwards, whereas the feet appear to the observers upwards towards the pole, thus we know that this happens so with the help of a mirror, until when the moon would arrive again at its point of rising above the horizon, this human-like figure stands upright as before […].[241]

Then, Triklinios proceeds to explain how readers themselves can re-enact the experiment and verify the results achieved through observation:

> However though, if someone would wish to gain what I call clearer knowledge through the experiment with the mirror, having assumed the present figure of the moon ⟨to be⟩ with the head turned in the direction of the pole, feet towards south, and taking up in their hands a big mirror and lifting it up high carrying it above, (s)he should go around starting with the figure from the moment of rising above the horizon, so that the shadow of the hypothesized figure would manifest itself in the mirror, until (s)he completes a circle having reached the place where (s)he had started. Thus, the knowledge of this matter would be obtained clearly.[242]

Michael Psellos is the richest source of information about experiments in the classroom involving devices. He often displayed the images projected by mirrors,[243] and following the suggestions of Heron and Archimedes he also built bronze/copper figures. He was also able to make the water from a bent siphon oscillate.[244]

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241 Wasserstein, "An Unpublished Treatise," p. 164, lines 87–91: ὑπὸ γῆν δὲ γινομένης καὶ τὰ κάτω μέρη διερχομένης, ἡ μὲν κεφαλὴ τοῦ τοιούτου σχήματος κάτω, οἱ δέ γε πόδες ἄνω πρὸς τὸν πόλον ὁρῶντες δείκνυνται, ὡς ἡμεῖς διά τινος κατόπτρου τοῦθ᾽οὑτωσὶ γινόμενον ἔγνωμεν, μέχρις ἂν εἰς ἀνατολὰς πάλιν ἀφιγμένης ὄρθιον ὡς πρότερον τουτὶ τὸ ἀνδρῶδες γένηται σχῆμα […]

242 Wasserstein, "An Unpublished Treatise," p. 165, lines 141–147: ἀλλὰ γὰρ εἴ τις τῇ τοῦ κατόπτρου πείρᾳ ὃ λέγω σαφέστερον γνῶναι βούλεται, τὸ παρὸν ὑποθεὶς τῆς σελήνης σχῆμα πρὸς πόλον τετραμμένην ἔχον τὴν κεφαλήν, τοὺς δέ γε πόδας πρὸς νότον, καὶ κάτοπτρον ἀνὰ χεῖρας λαβὼν μέγιστον, καὶ εἰς ὕψος ἀράμενος τοῦτο φέρων ἐπάνω περιΐτω τοῦ σχήματος ἐξ ἀνατολῶν ἀρξάμενος, ὥστε τοῦ ὑποκειμένου τὴν σκιὰν σχήματος ἐν τῷ κατόπτρῳ δείκνυσθαι, μέχρις ἂν κύκλῳ περιελθὼν πρὸς ὃν ἤρξατο γένηται τόπον, καὶ οὕτω τὴν γνῶσιν τούτου σχοίη σαφῶς.

243 *Oratoria minora* ed. Littlewood, or. 8, p. 35, lines 165–167; cf. also *Philosophica minora*, op. 55 lines 704–14 (pp. 261–62 Duffy)

244 *Oratoria minora* ed. Littlewood, or. 8, p. 35, lines 168–175.

In conclusion, in this chapter we have offered a survey of the available evidence of practices of scientific teaching and learning in Byzantium. While we have focussed on the study of the four mathematical sciences we have also stressed the importance of their relation to philosophy, as well as the prominence of related fields of study such as geodesy and medicine. Having started from the conceptual and institutional frameworks in which the transfer of scientific knowledge occurred, we have moved to different modes of knowledge organization as we find them in extant Byzantine codices, such as lists, questions and answers, commentaries, tables, and diagrammatic solutions. Importantly, we have also issued a warning regarding the difficulty in distinguishing between books produced for self-teaching and those produced for teaching of others. Finally, we can sum up by saying that Byzantine texts and manuscripts need closer examination in order to acquire a better understanding of everyday life at school. We hope that these examples may serve to clarify some misconceptions about the absence of a practical dimension in Byzantine science. Isidore of Miletus, who scared to death an annoying neighbour with a lightning machine and created an earthquake by means of steam-power, would not agree with those prejudices![245]

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245 Cameron, "Isidore of Miletus and Hypatia," p. 121.

CHAPTER 3

# Logistic, Arithmetic, Harmonic Theory, Geometry, Metrology, Optics and Mechanics

*Fabio Acerbi*

## 1 Introduction

This chapter covers all exact sciences apart from astronomy. The material, preceded by a section on scientific encyclopaedias, is arranged in thematic units; their order is the same as in the title, which reflects the traditional ordering of the disciplines in the scientific encyclopaedias called *Quadrivia*. It so happens that this ordering gives prominence to the strictly mathematical discipline most profitably practised by Byzantine scholars, namely, logistic. Each section, or part of it, is opened by a definition of its subject matter; this is followed by a survey and an assessment of the extant Byzantine sources; these are usually listed diachronically. Compressing so many disciplines into one single (and long) chapter requires me to make a choice between providing factual information and outlining a broad picture. Since ideology should be grounded on reality, I opted for the former. The intelligent and patient reader will certainly be able to bear the modicum of technical terminology this choice unavoidably entails. Apart from this, no mathematical training is required to follow my arguments.

As a matter of fact, I shall provide in this introduction and in the final section a sketchy and idiosyncratic narrative, mainly intended to explain why assessing Byzantine mathematical sciences other than astronomy is a difficult task. There are several reasons for this.

A number of sources still await an edition or have never been studied; therefore, part of the information contained in this chapter comes from my own research into manuscripts. The size and nature of unpublished or neglected writings covers a wide range:

- entire treatises, like some of the computational primers described below;
- coherent sets of annotations, like those of John Chortasmenos in his own exemplar of Euclid's *Elements*;[1]

1 Complete names of Byzantine scholars frequently mentioned in this contribution will be given only on their first occurrence in the main text. Orientation on these personalities can be found in the entries of the *Oxford Dictionary of Byzantium* or, for some of them, in those

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- scholarly or professorial elaborations, like those of Neophytos Prodromenos and of Chortasmenos himself;
- high-level school exercises, like those left by Cardinal Bessarion in some of his own manuscripts now preserved in the Biblioteca Marciana in Venice.

Byzantine scientific texts also present specific philological problems. On the one hand, their manuscript tradition is not infrequently based on a preserved autograph (such as George Pachymeres' *Quadrivium* or Theodore Meliteniotes' Ἀστρονομικὴ τρίβιβλος *Three Books on Astronomy*), or on a fair copy made under the control of the author himself (such as Barlaam's scientific writings or Theodore Metochites' Στοιχείωσις ἀστρονομική *Abridged Astronomical Elements*),[2] or at least on almost contemporary transcriptions (such as most of Isaac Argyros' writings). On the other hand, the phenomena of enrichment and block-contamination typical of technical texts (in particular those of a markedly sectional nature)[3] are not, as in the case of ancient Greek writings of the same kind, relegated to unattainable layers of transmission. Nor were they regularized by a campaign of recensions and re-editions of scientific texts comparable to those undertaken in Alexandria in late antiquity.

Ancient Greek mathematics obviously overshadows Byzantine mathematics, simply because the latter consciously shaped itself with reference to the former. Therefore, the historian studying Byzantine mathematics must resist the temptation of assessing it using the categories of "originality" or of "relevance." Characteristic of this attitude is P. Tannery's judgement passed on the writings of Nicholas Rhabdas' whose edition he nevertheless published two

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of the *Prosopographisches Lexikon der Palaiologenzeit* (*PLP* henceforth), at the following numbers: Planudes (died *c.* 1305), no. 23308; Pachymeres (d. *c.* 1310), no. 22186; Pediasimos (d. 1310–14), no. 22235; Bryennios (*c.* 1300–20), no. 3260; Moschopoulos (*c.* 1305), no. 19373; Metochites (d. 13/3/1332), no. 17982; Rhabdas (*c.* 1321–40), no. 1437; Barlaam (d. 1348), no. 2284; Gregoras (d. *c.* 1358–61), no. 4443; Prodromenos (*c.* 1330–60), no. 19254; Argyros (d. *c.* 1375), no. 1285; Meliteniotes (d. 8/3/1393), no. 17851; Kydones (d. 1397–98), no. 13876; Chortasmenos (d. 1431), no. 30897; Plethon (d. 26/6/1452), no. 3630; Bessarion (d. 18/11/1472), no. 2707. For all ancient Greek scholars mentioned in what follows, see the entries in the *Dictionary of Scientific Biography*. The best previous overall introductions to Byzantine science, including substantial sections on the subjects treated in the present chapter, are Vogel, "Byzantine Science," and Tihon, "Sciences exactes."

2 The manuscripts involved are: Pachymeres: Roma, Biblioteca Angelica, gr. 38; Meliteniotes: Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 792; Barlaam: Venezia, Biblioteca Nazionale Marciana, gr. Z. 332; Metochites: Vat. gr. 182 and 181.

3 "Enrichment" means that campaigns of interpolations of self-contained textual units (lemmas, theorems, prescriptions) were put to effect, and that these additions migrated, in mass or selectively, from one recension to the other. Block-contamination occurs when substantial segments of a treatise are copied from models belonging to different branches of the textual tradition.

years later: “L’intérêt de ses écrits est surtout de montrer jusqu’où étaient tombés les héritiers dégénérés du nom hellène, ceux-là même qui avaient alors Diophante entre leurs mains.” If this could be taken to be a “factually correct statement,” it still “does not tell the whole story”—and it is the whole story what we are interested in.[4]

One cannot hide the fact that Byzantine scientific production (and not only scientific production) suffers from an embarrassing persistence of what *we* would call “plagiarism” among “colleagues.”[5] We can read Maximos Planudes writing a primer on elementary arithmetical operations using Hindu-Arabic numerals (called ψηφηφορία κατ’ Ἰνδούς or “calculation according to the Indians”) that draws to a large extent on a previous treatise of an anonymous author. Another writer, Rhabdas, in his *Letters*, patently transcribes the beginning of Diophantos’ *Arithmetics*, and in fact, in his *Letter to Khatzykes*, tacitly recycles a previous treatise of anonymous author. In Book II of his *Abridged Astronomical Elements*, Metochites plunders page after page of the astronomical section of Pachymeres’ *Quadrivium*; Argyros appropriates the method of the Easter Computus already expounded in Rhabdas’ *Letter to Tzavoukhes*. Almost every writer on the extraction of approximate square roots describes exactly the same second-order approximation (namely, the standard, iterated Heronian one) but pretends that it was his own original elaboration. Meliteniotes presents as Book III of his *Three Books on Astronomy* an introduction to Persian astronomical tables almost certainly written by someone else. Chortasmenos appropriates *verbatim* Book V of Barlaam’s *Logistic*.

One might say that the *extent* of the phenomenon is bewildering, not merely its existence. Ancient Greek mathematicians and commentators on mathematical matters not infrequently “forget” to record their sources: it is sufficient to recall the striking similarity of some solutions to the problem of the duplication of the cube,[6] or the relations between Pappus’ and Theon’s commentaries on Ptolemy’s *Almagest*. Maybe the diffusion of “plagiarism” is just another facet of Byzantine encyclopaedism, or “cultura della *syllogê*,”[7] or a compilatory habit, or whatever we want to call it. One only has to think of Michael Psellos’ (b. 1018) wide-ranging literary output, made up by and large of compilations of

4 The first quote is from Tannery, “Manuel Moschopoulos et Nicolas Rhabdas,” p. 15, the second from Neugebauer, “Wretched” (read also Barnes, “Syllogistic,” n. 9 on p. 98). Tannery’s works will be cited according to the pagination of the *Mémoires Scientifiques*.

5 It goes without saying that Byzantine writers systematically plundered ancient Greek authors. The reader will also profitably compare Tannery, “Manuel Moschopoulos et Nicolas Rhabdas,” p. 15, with Allard, “Petit traité,” p. 11.

6 Best account in Knorr, *Textual*, pp. 11–153. Read also Porphyry’s complaint about Ptolemy’s systematic plagiarisms in his *Harmonics*: *Commentary*, ed. Düring, p. 5.7–16.

7 See Odorico, “Cultura.”

ancient sources. Still, one must also take into account that we can assume that we have a fairly complete documentary record of Byzantine science though this is not the case for ancient Greek science, and incompleteness cannot but reduce the phenomenon. In addition Byzantine science was produced over a very short period, more or less in one and the same place, by people belonging to a very restricted elite and therefore acquainted with each other. This acquaintance was frequently strengthened by a master-pupil relation, where appropriation was a form of faithfulness to the master.[8] Another point to be considered here is that we cannot assume that something written in, for example, 14th-century Constantinople, even edited, even endowed with a preface—but intended for a very limited readership—was necessarily felt as "published" and as a result to be connected with a particular author. Consequently, one might wonder whether these so-called "plagiarisms" would have really constituted a problem in Byzantium.

The reference class of Byzantine mathematicians coincides with the whole Byzantine intellectual elite: finely literate monks, notaries, high-ranking functionaries and ecclesiastics, professors in institutions of higher education—all of them more or less explicitly encouraged by Imperial patronage. We must bear in mind that, if professors were a negligible minority and if no "specialist" of mathematics or astronomy ever existed in Byzantium,[9] the same was also true for Greek antiquity: professional teachers of high-level mathematics are an invention of late antiquity; the mathematicians of the Hellenistic period were simply wealthy and talented people with enough leisure to practice mathematics. This was possible in the proto-capitalistic system openly based on the slavery that characterized Greek antiquity—and will again be possible in the capitalistic system covertly based on the slavery that characterizes the early Modern era—but it was simply impossible in Byzantine society, immobile and sharply pyramidal, and consciously living under the intellectual shadow of ancient Greece. In this respect, if the Fourth Crusade *may have* occasioned the loss of so many manuscripts, it *certainly* introduced a discontinuity that eventually triggered the phenomenon of the Palaiologan Renaissance, which was particularly striking in the scientific domain. As the well-known story of Metochites learning astronomy privately from marginalized Manuel Bryennios shows,[10] Byzantine scholars had to make a new start on appropriating the

8 Note also the *prima facie* surprising number of scientific authors who sided with the anti-Palamite party (the best introduction to the controversy is still Mercati, *Notizie*); maybe we may content ourselves with remarking that the anti-Palamites are the "rationalist" party of the controversy.

9 Nor did professional philosophers exist: Ebbesen, "Greek and Latin," pp. 75–77.

10 In the long description of his own *apprentissage* with Bryennios, Metochites almost exclusively mentions authors and treatises related to geometry and astronomy (*Abridged*

Greek heritage. This fact, combined with fresh material coming from nearby civilizations, gave rise to the sudden development of scientific production that characterizes the 14th century.

One must be careful in interpreting the accounts of the teaching of scientific disciplines within institutions of low- or middle-level education as being signs of a *technically well-informed concern* with these disciplines. On the contrary, the impression one gets from surveying such accounts is that they more or less repeat the same standard version based on a division of disciplines according to the *Quadrivium*. If one tries to squeeze some content out of these documents, the result amounts to no more than the mention of a handful of conventional names such as Euclid, Diophantos, or Nikomachos, and with such a poor technical record as to make one suspect that low- or middle-level teaching did not go much beyond learning some definitions by heart. A case in point (referring to the years just preceding the Latin conquest of Constantinople) comes from a long passage by Nicholas Mesarites.[11] Illustrating the courses held in the Patriarchal School, he describes a *Quadrivium*-minus-astronomy in which arithmetic is entirely reduced to arithmology (see below), geometry to a short list of (mainly solid) figures met here and there in Euclid's *Elements*—supplemented with an allusion to a phenomenon (the halo) whose geometrical analysis we find in Aristotle's *Meteorology*—whereas harmonic theory amounts to something that was deemed "almost entirely nonsensical."[12] If we are to believe Metochites' complaint about the dearth of interest in scientific matters that he experienced during his youth, even the new order of study introduced by Nikephoros Blemmydes (d. *c.* 1271/73; PLP 2897) during the Nicaean period apparently yielded no striking results.[13]

*Astronomical Elements*, ed. Bydén, I.1.28–39, and in particular section 32): these are Ptolemy, *Almagest*, and as a preliminary to it, Euclid, ⟨*Elements*⟩, *Optics*, *Catoptrics*, *Data* and *Phaenomena*; Theodosios, *Spherics*; *On locations*, *On days and nights*; ⟨Autolycus⟩, *On risings and settings*, *On a moving sphere*; ⟨Nikomachos⟩, *Introduction to arithmetic* and maybe also ⟨Diophantos, *Arithmetica*⟩ (the overall designation for arithmetical matters is ἀριθμητικῶν εἰσαγωγαὶ καὶ βαθύτεραι θεωρίαι); Apollonios, *Conics*; Serenos, *On the section of a cylinder* (called κυλινδρικά). A general warning on the reliability of Metochites' account about his studying with Bryennios is in order: in *mathematical* matters, it was mostly inconvenient, and an easy polemical target for opponents, to be *amathês*, that is, not a pupil of some master; see Ševčenko, *Études*, n. 6 on pp. 115–16.

11 *Description* XLII.6–9, ed. Downey; cf. the list of eponymous scholars at XLIII.5: Nikomachos, Euclid, Ptolemy—the latter for harmonic theory and not for astronomy!

12 Wellesz, *History of Byzantine Music*, p. 63.

13 According to Gregory of Cyprus (d. 1290; PLP 4590), *Autobiography*, ed. Lameere, p. 185.15–17, George Akropolites (d. 1282; PLP 518; he was a pupil of Blemmydes) successfully lectured on Euclid (geometry) and Nikomachos (arithmetic) in freshly recovered Constantinople. Among his students were Pediasimos and Pachymeres.

Metochites' testimony also shows that higher-level mathematics was initially transmitted through the same channel as was used in Greek antiquity: private dealings with a master. This explains the filiation Bryennios-Metochites-Gregoras-Argyros in technical matters (aptly supported by the library gradually gathered in the Chora monastery),[14] and the less productive filiation Prodromenos-Chortasmenos-Bessarion, certainly connected with an institution of higher education such as the *Xenôn* of the King of Serbia attached to the monastery (and to the renowned library) of St. John Prodromos in the Petra district of Constantinople.[15] Within the first intellectual succession just mentioned, we do not have any evidence that Metochites' *Abridged Astronomical Elements*, written in his typically verbose style, was (or actually could be) used to teach anything to anyone. The only, and magnificent, written production which was certainly connected with teaching is Chortasmenos' celebrated notebooks,[16] whose pedagogic virtuosity in scientific matters has never been studied.

It must be stressed that Chortasmenos' notebooks are just one instance within a range of literary genres wider than the one we are accustomed to when studying the scientific output of ancient Greece. Such a wealth of genres is not a distortion produced by our techniques of analysis of literary products, but was entertained in full awareness by Byzantine authors. We thus read *Quadrivia*, monographic treatises, primers, compendia, commentaries, epistles, collections of scholia, isagogic collections featuring mathematical principles and explicative annotations, notebooks, collections of tables (and not only astronomical tables), *Rechenbücher*,[17] completions, refutations, and recensions of other treatises. There is simply no reason to introduce a grading among these products, whether it based on quality, diffusion, structural completeness, stylistic accomplishment, or whatever parameters. They all exist on a par with each other, and delineate Byzantine mathematical sciences. Some of them are second-order scholarly activities on ancient Greek writings; most of them are connected with what I would call "sectional mathematics," namely, works that can easily be, or that actually are partitioned in independent sections.

The relationship of perfect continuity with the mathematics coming from Greek antiquity is witnessed by the research themes, but is most conspicuously

14 For these filiations see chapter 2 of this volume.

15 On the complex history of this institution, see Cacouros, "Philosophie."

16 See Canart/Prato, "Les recueils," for their structure. Scraps of student's mathematical and astronomical notebooks are, e.g., Isidore of Kiev's (d. 31/3/1462; *PLP* 8306) in Vat. gr. 1852, fols. 212r–259r, and Bessarion's in Marc. gr. 526, fols. 176r–195v (in Greek) and 168r–175r, 196r–199r, 208r–211r, 216r–225r (in Latin). Both were Chortasmenos' pupils.

17 For a definition, see p. 124 in the section on *Logistic* and Acerbi, "Rechenbücher."

stressed at the stylistic level: the three main stylistic codes of Greek mathematics were assimilated and perfectly reproduced, with subtle variations, contaminations, and developments that attest to an active mastery of them. These are the demonstrative, procedural, and algorithmic codes.[18]

The demonstrative code is the one in which ancient Greek geometry is written and needs no description. In logistic, the solution of a numerical problem, usually formulated without any supporting proof, was encoded in two peculiar expository formats, namely, the procedural and the algorithmic code. These are two stylistic resources that describe chains of operations on numerical entities, such that the output of an operation is taken as the input of the subsequent operation: they are the ancient counterpart of our computer programmes. In particular, the procedural code was aptly used to formulate operational sequences that we would condense into an algebraic "formula."

The procedural code formulates its prescriptions as a sequence of coordinated principal clauses with the verb in the imperative or in the first person plural, present or future; to each principal clause are subordinated one or more participial clauses coordinated with each other. This code is used to formulate operatory prescriptions in the most general way; the mathematical objects involved are identified by (sometimes extremely long) definite descriptions; the verbal forms—either finite or participial—represent the operations. The algorithmic code resorts instead to paradigmatic examples featuring specific numerical values. It formulates its prescriptions as a sequence of principal clauses coordinated by asyndeton; each clause formulates exactly one step of the algorithm and comprises a verbal form in the imperative (this is the operation) and a system of two complements, a direct one and an indirect one, in the form of numerical values (these are the operands). The result of each operation is identified in a further clause, with the verb in the present indicative (forms of γίγνομαι "to yield"), sometimes replaced by an adjective in the predicative position. These syntactical structures are both equivalent to our equality sign "=."

A simple example comes from a problem ascribed to Argyros,[19] in which a prescription is provided to calculate the sum of an arithmetic progression as far as a certain number; the prescription is first formulated as a procedure, then as an algorithm (paradigmatic example: the arithmetic progression goes from 1 to 15):

18 These notions were first introduced in Acerbi, "Codici stilistici."

19 See p. 136 in the section on *Logistic* and Acerbi, "Problemi," for an edition and a commentary. The example is "simple" because no participial clause is present in the procedure.

> λαμβανέτω τὸ 𐅵 τοῦ ἀριθμοῦ τοῦ μέχρις οὗ ἡ ζήτησις γίνεται, καὶ προστιθέτω τούτῳ μονάδος 𐅵, καὶ τὸν γινόμενον πολλαπλασιαζέτω μετὰ τοῦ ἀριθμοῦ οὗτινος εἰλήφει τὸ 𐅵, καὶ τὸν γινόμενον αὖθις γινωσκέτω εἶναι τὴν τῶν ἀριθμῶν σύνθεσιν. οἷον ὡς ἐπὶ τοῦ προϋποδειχθέντος ἀριθμοῦ τοῦ ιε· τούτου τὸ 𐅵· ζ 𐅵· πρόσθες μονάδος 𐅵· γίνονται η· ταῦτα πολλαπλασίασον ἐπὶ τὸν ιε· γίνονται ρκ.
>
> Let one take ½ of the number as far as which the research arrives, and let one add ½ of a unit to this, and let one multiply the resulting ⟨number⟩ with the number of which one has taken ½, and let one recognize the resulting ⟨number⟩ as the sum of the numbers. For instance, for the number 15 indicated above; ½ of this: 7 ½; add ½ of a unit: they yield 8; multiply those by the 15: they yield 120.

The prescriptions in the geometric metrological corpus[20] are almost exclusively formulated by means of algorithms. Ptolemy's *Almagest* contains dozens of procedures but no algorithms; this is also the style adopted in most technical passages of Theon's commentaries on Ptolemy's treatises (namely, the *Almagest* and the *Handy Tables*), in Stephanus' commentary on the *Handy Tables* and in the *Prolegomena to the Almagest*. As we shall see, these astronomical writings will set the stylistic standard for an entire branch of strictly mathematical Byzantine production.

A phenomenon analogous to the proliferation of scientific literary genres, and connected with it, is the multiplication of subject-matter. This is also connected with the practice, already well-established in late antiquity, of crossing stylistic registers. One must concede that such interwoven proliferations are probably more apparent to our analytical perception than they would be to Byzantine eyes, which may well have seen disciplines perfectly fitting a standard *Quadrivium* everywhere. To see where the problem lies, Byzantine scholars would include Diophantos' *Arithmetics*—whose demonstrative style and mathematical contents are naturally assigned to "arithmetic," that is, our "number theory"—in what I call "logistic," because the latter was canonically characterized as the discipline in which a unit is not indivisible;[21] on the other hand, in a strict *Quadrivium* perspective, logistic matters were placed under the heading "astronomy," since this is the science in which calculations were traditionally performed requiring the introduction of parts of a unit. But to

20 "Geometric metrology" explains how to measure geometric figures, as in Hero's *Metrics*. I adopted this denomination to avoid confusions with "metrology," dealing instead with units of measurement. A treatise of "geometric metrology" may include a "metrological" section in the latter sense.

21 The standard ancient account is Eutocios', in Archimedes, *Opera omnia*, vol. 3, ed. Heiberg, p. 120.28–30.

categorize Diophantos as "astronomy" is utter nonsense, and in fact we find him in the arithmetic section of Pachymeres' *Quadrivium*.[22] For these reasons, the partition into arguments I have adopted in the following pages cannot be precise, and is to a large extent conventional.

## 2 *Quadrivia* and Scientific Encyclopaedias

A *Quadrivium* is a scientific encyclopaedia organized in four sections that follow each other in a standard order of decreasing abstractness: arithmetic, harmonic theory, geometry, astronomy.[23] Three complete Byzantine *Quadrivia* are extant.[24]

– A *Quadrivium* (henceforth *Anonymus* 1007; the current denomination is "Anonymus Heiberg") written in the second half of year 1007 and variously attributed, by manuscript subscriptions or modern scholars, to a number of people, among whom is Michael Psellos.[25] This *Quadrivium* is in fact part of a larger writing, whose first section expounds the basics of Aristotelian logic (categories, syllogism, and fallacies). The final subscription (fol. 181r) of its main witness Heidelberg, Universitätsbibliothek, Palatinus gr. 281, copied by Nicholas the Calligrapher in January 1040, seemingly ascribes its contents to some Romanos, *asekretis* and who was a judge in Seleucia. However, the subscription comes after a number of other writings and its formulation ἡ βίβλος … ἐκ πολλῶν πονημάτων Ῥωμανοῦ … συλλεγεῖσα … καὶ αὐθέντου μου "a book collected from the several works of Romanos … and that I myself enriched" does not constitute a firm basis for any attribution. The date of composition is established on the basis of the description, contained in the astronomical part of the *Quadrivium*, of a procedure of conversion from an Egyptian date into a Julian one in which the current year is given as a.m. 6516 (= 1 September 1007 to 31 August 1008).[26] However, the procedure is only valid if the intended date falls between 30 August and 14 December

22 As we shall see, Barlaam's *Logistic* is a treatise of number theory written in impeccable Euclidean style.

23 A *locus classicus* for a characterization of the *Quadrivium* is Metochites, *Abridged Astronomical Elements*, ed. Bydén, I.2.10–13.

24 We have no documents giving us reason to think that any *Quadrivium* was composed in Greek antiquity; in the Latin world, Martianus Capella's *De nuptiis Mercurii et Philologiae* contains a *Quadrivium*. I shall provide in the subsequent sections detailed analyses of some thematic sections of the Byzantine *Quadrivia*.

25 Edition *Anonymus* 1007; see also Moore, *Iter Psellianum*, PHI.170. The ascription to Psellos, who was born in 1018, is of course impossible. The initial inscription Συνοπτικὸν σύνταγμα φιλοσοφίας *Compendium of philosophy* is only the title of the first section.

26 *Anonymus* 1007, ed. Heiberg, pp. 107.27–110.11.

1007.[27] The sections on arithmetic and geometry are honest compilations of definitions, some enunciations of propositions, and five (geometrical) proofs; the material is mainly drawn from Nikomachos' *Introduction to Arithmetic* and Euclid's *Elements*. The bulk of the section on astronomy is made of prescriptions drawn from a primer, still to be identified, to Ptolemy's *Handy Tables*.[28]

– Pachymeres' *Quadrivium*, entitled Σύνταγμα τῶν τεσσάρων μαθημάτων,[29] whose autograph is Roma, Biblioteca Angelica, gr. 38. Pachymeres was a pupil of George Akropolites, whom Michael VIII (r. 1261–82) charged with the responsibility for restoring higher education within the Patriarchal School in Constantinople after 1261. Pachymeres was also a teacher in the same school. His *Quadrivium* is much more developed and articulated than *Anonymus* 1007. Ancient sources are listed in Tannery's apparatus, except the section on harmonic theory.[30] Contents of the other sections are as follows. Arithmetic. §§ 1–24 and 45–46: in the style of Nikomachos and containing several extracts from his *Introduction*; §§ 25–44: a compilation of definitions and few enunciations (up to *Ar.* I.11) from Diophantos' *Arithmetics*, with exemplifications and expansions apparently original to Pachymeres; §§ 47–74: definitions and several enunciations from Euclid's *Elements*, Books II (number-theoretical version) and VII–IX, all enunciations being corroborated by numerical examples. Geometry. §§ 1–58: definitions and several enunciations, endowed with proofs or geometrical exemplifications, from Euclid's *Elements*, Books I–II (§§ 1–4), V–VI (5–14), III (14–15), X (16–39; particularly detailed), XI–XIII (40–47), XIII (49–54), "XIV–XV" (55–58), with a cube duplication[31] expounded in § 48; §§ 59–76: definitions and propositions, with proofs, from Euclid's *Optics*, recension A.[32]

27 See Taisbak, "Date."

28 Some ancient sources of *Anonymus* 1007 are summarily listed in Heiberg's apparatus; a detailed analysis of the section on Aristotelian logic is in Barnes, "Syllogistic," of that on arithmetic is in Zeegers-Van der Vorst, "L'arithmétique," of that on harmonic theory is in Richter, "Überlieferungen," pp. 94–98. The section on geometry also contains a number of extracts from Proclus' commentary on Book I of the *Elements*. The section on astronomy ends with a short summary of basic astrological notions (aspects, temperaments, houses): *Anonymus* 1007, ed. Heiberg, pp. 115.22–119.25.

29 Edition Tannery, *Quadrivium*.

30 For which see below and the detailed analysis accompanying the edition in Vincent, *Notice*, pp. 384–553; see also Düring, *Ptolemaios und Porphyrios*, pp. 8–9, who lists the borrowings from Ptolemy and Porphyry, and the discussion in Richter, "Überlieferungen," pp. 98–101.

31 By means of Hero's method, here ascribed to Apollonios.

32 The only manuscripts that contain Euclid's *Elements* and *Optics*, recension A, and that certainly or likely precede Pachymeres are Wien, Österreichischen Nationalbibliothek, phil. gr. 31, Oxford, Bodleian Library, Auct. F 6 23 (beginning 12th and 2nd half of 11th

Astronomy. §§ 1–6 and 26: a primer of logistic (see next section); §§ 23–24: material related to the construction of the table of chords in Ptolemy, *Almagest* I.10. The rest of this section is a series of arguments based on a number of authors, among whom are Euclid (*Elements*, *Optics* and *Phaenomena*), Aristotle (*On the Heavens*), Ptolemy, *Almagest*, and Theon's commentary thereon, Cleomedes, Theodosios (*On locations*), Aratos and Hipparchos' commentary thereon.

– A part of an encyclopaedia written by the early 14th-century polymath Joseph Rhakendytes (d. 1330; *PLP* 9078), based in Thessaloniki and in correspondence with Metochites, Manuel Moschopoulos, and Nikephoros Gregoras. It is mere plagiarism, with slight modifications, of *Anonymus* 1007.[33] The plagiarism is so exact that Heiberg, in his edition of *Anonymus* 1007, and Moore, who lists ninety-five manuscripts of the same work,[34] take a number of manuscripts containing Joseph' encyclopaedia as witnesses of *Anonymus* 1007.

Other scientific encyclopaedias were conceived according to a different principle, namely, collecting as many Greek scientific texts as possible in the same manuscript. This could be made either by a scholar gathering disparate transcriptions or by a copyist deliberately shaping one or more codex in this way. We know of at least three such source-based encyclopaedias.[35]

– Vat. gr. 191 (2nd half of 13th century),[36] assembled, annotated between 1296 and 1302/3, but definitely *not* coordinated—and actually showing no traces of intelligent coordination—by John Pediasimos. The contents are elementary astronomy (the collection of treatises known as "little astronomy"), astrology, geography, harmonic theory, arithmetic.

century, respectively), Firenze, Biblioteca Medicea Laurenziana, Plut. 28.6 (2nd half of 13th century; it is a copy of the Wien manuscript), and Paris, Bibliothèque Nationale de France, gr. 2345 + Vat. gr. 1316, fols. 337–52, transcribed about the next-to-last decade of 13th century (Bianconi, "Le pietre e il ponte," pp. 141–47) and an apograph of the Bodleian manuscript.

33 See Criscuolo, "Note." *Anonymus* 1007 and Rhakendytes' encyclopaedia happen to contain two of the three existing Byzantine handbooks of logic; the third is Blemmydes' *Logical compendium* (*Patrologia graeca*, vol. 142, cc. 686–1004), apparently Rhakendytes' logical source: Ebbesen, "Greek and Latin," n. 1 on p. 83.

34 Moore, *Iter Psellianum*, PHI.170.

35 See my analysis, with bibliography, in Acerbi, "Byzantine Recensions," pp. 154–60 and 192–95.

36 See Turyn, *Codices*, pp. 89–97 and pll. 54–69, and Bianconi, "Libri e mani," pp. 324–30 and fig. 1, in particular for the structure of the codex. A thorough analysis of Laur. Plut. 28.6 and of Vat. gr. 191 and 192 is now in Acerbi/Gioffreda, "Manoscritti."

- Vat. gr. 192 (2nd half of 13th century), of whose origins and aims we know nothing. The contents are geometry, elementary astronomy, harmonic theory.
- A huge *Quadrivium* in two tomes, Par. gr. 2342 and Vat. gr. 198, transcribed by the copyist Malachias in the 60s–70s of 14th century.[37] The Paris manuscript contains geometry and elementary astronomy, the Vatican codex arithmetic, harmonic theory, advanced astronomy (Ptolemy). Malachias repeatedly added notes attesting to his collations among several manuscript sources. This scribal *tour de force* certainly required several years to achieve, and one of its most remarkable features is that Malachias endowed most of the treatises he transcribed with commentaries arranged in the margins; we can read in this position Eutocios' commentary on Apollonios' *Conics*, Philoponos' commentary associated with Nikomachos' *Introduction*, and Porphyry's commentary in the margins of Ptolemy's *Harmonics*. An imposing and multi-layered scholiastic apparatus surrounds the *Elements* and the *Almagest*. Almost all treatises in these manuscripts are read in Byzantine recensions.

The last avatar of scientific encyclopaedism in Constantinople is Mordekhai Comtino's (d. 1482) *Book on Computation and Mensuration*.[38] This is written in Hebrew but among its sources in Greek are of course Nikomachos' *Introduction* and Euclid's *Elements*, and also geometric metrological writings and Hero's *Metrics*, whose only known manuscript witness Comtino had in his hands. His treatise includes sections on numerical notations, the four elementary operations, an arithmetical version of *Elements* II.1–10 (it is not clear whether drawn from Pachymeres, or from Barlaam, or from neither of them), operations with fractions, rule of three, twenty-one *Rechenbuch*-problems, geometric metrological problems.

## 3 Logistic

Logistic is a branch of arithmetic in which a unit can be divided and that deals with numbers as representing concrete entities and with calculations connected with them. Logistic was extensively developed in late antiquity as a support to mathematical astronomy, and also played the same role in the Byzantine period.[39] The first known treatise of this kind is included in the *Prolegomena*

37 On Malachias see Mondrain, "Constitution," pp. 19–24.

38 Described in Schub, "Mathematical Text"; details on the metrological section in Hero, *Metrica*, ed. Acerbi/Vitrac, pp. 549–56.

39 See below for Barlaam's explicit statement in this sense. The most comprehensive introduction to Greek and Byzantine logistic is still Vogel, *Logistik*.

*to the Almagest*, and amounts to the (non-redacted) lecture notes of a course held in the circle of the Neoplatonic philosopher Ammonios. This treatise is a computational primer to the *Almagest*: a tightly organized "handbook of logistic" featuring as its main themes an introduction to the sexagesimal system, a description of computational algorithms for multiplication, division, and extraction of an approximate square root, a presentation of interpolation techniques, and an exposition about compounded ratios and removal of a ratio from a ratio.[40] According to the anonymous author, no comprehensive previous exposition of this kind existed—and in fact none has been transmitted to us.

This handbook set the standard for all similar primers composed in Byzantine times. As astronomy was the science mostly investigated by Byzantine scholars, handbooks of logistic form a significant part of the Byzantine scientific output. For the same reason, logistic issues prominently figure in the astronomical part of Pachymeres' *Quadrivium*. Moreover, the introduction of the decimal positional system in mid-13th-century Constantinople took the form of a couple of handbooks of logistic; this textual format, however, was not the most conducive to explain how to calculate with fractions i.e. non-sexagesimal parts of a unit.[41] Logistic texts are usually written in procedural and algorithmic style, with only sporadic intrusions of the demonstrative code. Procedures precede paradigmatic examples presented in algorithmic form, and are intended to validate them. Algorithms are frequently replaced—or accompanied—by tabular arrangements of the performed operations. As a matter of fact, the latter are nothing but an evolution of the former in a more transparent format.[42]

As there are many logistic writings, and many of them deal more or less with the same matters, I have set out the data about the contents of these writings in a table, which the reader will find in the Appendix. I have included there all texts I shall mention in this section, a list of which follows.[43]

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40 The last argument in the list had a *Fortleben* whose extent is almost incredible to modern minds: see Acerbi, "Composition," and the next section for a short account. For the *Prolegomena*, see the study in Mogenet, *Introduction*, and the edition of the non-logistic portion in Acerbi/Vinel/Vitrac, "*Prolégomènes*."

41 Such explanations were instead included in *Rechenbücher* (see below in this section). A first assessment of the interplay between unit fractions and common fractions is in Acerbi, "Rechenbücher."

42 In the computational primer included in Meliteniotes' *Three Books on Astronomy*, each operation is described three times: by means of a procedure (called μέθοδος), of an algorithm (ὑπόδειγμα "example"), and of a tabular set-up (ἔκθεσις τῶν ἀριθμῶν "setting-out of the numbers").

43 All mentioned sources that can as yet be read only in manuscript form will be edited in Acerbi, *Logistic Texts*. Add to the list a number of short texts on interpolation techniques; two of them are recorded in Tihon, *Petit Commentaire*, nos. 95–96 on pp. 368–69.

- *Anonymus* 1183, within a *Ur-Rechenbuch* (see below), a detailed collection of procedures for decomposing common fractions into unit fractions, presented as usual in the form of division of numbers 1 … *n* by *n*, with *n* = 5 … 12, followed (fols. 44v–46v) by a list of the mere results of the same decompositions, ranging this time from 5 to 20.
- *Anonymus* 1252, a handbook of logistic using a positional decimal system with "Indian" figures, entitled Ψηφηφορία κατ' Ἰνδοὺς ἡ λεγομένη μεγάλη *Great calculation according to the Indians*.[44] It includes: a description of the decimal notation used; methods for addition, subtraction, multiplication, and division; an Easter Computus, assuming 1252 as current year; an exposition of calculations involving signs, degrees, and minutes on the zodiacal circle;[45] extraction of an approximate square root (first-order Heronian approximation). All methods are counter-checked;[46] for instance, the square root is checked by multiplication. Some cumbersomeness in the exposition comes from the proliferation of cases, supposedly required by the varying quantity of digits in a number and by the presence of zero (τζίφρα) among them. Western Arabic numerals are used.[47]
- Planudes, Ψηφηφορία κατ' Ἰνδοὺς ἡ λεγομένη μεγάλη *Great calculation according to the Indians*, a handbook of logistic largely inspired by *Anonymus* 1252.[48] It is also partly extant in the autograph Milano, Biblioteca Ambrosiana, & 157 sup.[49] The plan is the same as that of *Anonymus* 1252; however, the Easter Computus is eliminated, the section on square root reaches to the second-order Heronian approximation and is enriched by a standard method, carried out within the sexagesimal system, based on *Elements* II.4, and well-known at least since Theon's *Commentary on the Almagest* (Planudes' example is the same as Theon's). A final section with disparate problems is

44 Edition *Anonymus* 1252.

45 This is a mixed and periodic duodecimal-sexagesimal system in which 30 degrees = 1 sign; it was currently in use among 14th-century astronomers.

46 The check is called δοκιμή.

47 On Hindu-Arabic numerals in Byzantine scientific texts and manuscripts (where they first appear during the 12th century) see Vogel, "Buchstabenrechnung"; Wilson, "Miscellanea," pp. 400–404; Burnett, "Numerals."

48 Edition Planudes, *Great calculation*. The relation is obvious once one compares the two texts. We also know, from a letter of Planudes to George Bekkos (Planudes, *Letter* 46, ed. Leone, p. 80.8–18), that he happened to own a book on κατ' Ἰνδοὺς ἀριθμός "number according to Indians" and that he was composing his own, in which he would have added expositions of the parts about how to find the square number nearest to a given non-square number, and the side of a given square number (*sic*). In the same lines of Bekkos' letter, the ease is remarkable with which Planudes treats the issue of appropriating his source.

49 Turyn, *Dated*, pp. 78–81 and pl. 57; Allard, "*Ambrosianus*."

certainly spurious. Verbosity, a few alternative methods, and a more abundant set of examples make Planudes' treatise much longer than its source. The numerals are in the Eastern Arabic form, also found in "Persian" astronomical tables in Vat. gr. 211 (end 13th century) and 1058 (middle 14th century). Rhabdas revised Planudes' *Great calculation*, and his recension is transmitted, possibly incomplete, in a number of manuscripts;[50] other, disparate texts were added during the 14th century.[51]

– Pachymeres, *Quadrivium*. A short but complete computational primer to matters relevant to astronomy is contained in §§ 1–6 and 26 of the corresponding section.
– Rhabdas, *Letter to Khatzykes*.[52] It contains: denominations of numbers and numerical notation;[53] how to represent integers from 1 to 9,999 on the fin-

50 This is borne out by the titles in the manuscripts themselves—the revision, best attested in Vat. gr. 1411 (early 15th century), also includes to a couple of short additions; the text ends, in the middle of fol. 126v, at Allard, Planude, 61.8 εἴρηται. Edition of Rhabdas' additions in Planudes, *Great calculation*, ed. Allard, pp. 203–11. At the end of Rhabdas' *Letter to Khatzykes*, the reader is referred to more complex expositions of multiplication and division to be found in the Ἰνδικὴ μεγάλη ψηφοφορία "Great Indian Calculation" (Tannery, "Notice," pp. 114.3 and 114.14). This reference is absent in Rhabdas' source (see note 52 just below).

51 The additions are absent in Firenze, Biblioteca Medicea Laurenziana, Ashburnham 1599, fols. 153r–175v (14th century), of which Vat. gr. 1411 is a partial copy embodying the corrections of a reviser of the Florence manuscript. The Vatican manuscript is important since Tannery ("Notice," pp. 73, 76 and 82–83) surmised that it was a copy of a codex, maybe of logistic and arithmetical contents, conceived and realized by Argyros and, before him and in part, by Rhabdas. Tannery's contention is grounded on the title of Moschopoulos' treatise on magic squares (see below), on the presence, in Vat. gr. 1411, of three short arithmetical texts ascribed to Argyros (see below), of *recensio* II of Philoponos' commentary on Nikomachos' *Introduction*—a recension Tannery ascribes to Argyros himself—and of two additions to Rhabdas' additions (!) to Planudes' *Great calculation*, marked in the margin by a mysterious τοῦτο ἡμέτερον (Vat. gr. 1411, fols. 123v and 125v; these are also edited in Planudes, *Great calculation*, ed. Allard, pp. 205 and 209).

52 Edition Tannery, "Notice," pp. 86–116. As a matter of fact, Rhabdas deftly appropriated a previous, and shorter (for instance, no method for the extraction of a square root is expounded), treatise of anonymous author: Acerbi/Manolova/Pérez Martín, "Anonymous."

53 A lower left slanting stroke marks thousands, a superimposed trema marks myriads. Higher numerical orders are denoted by cumulating such marks. Recall that the Greek numerical notation (see Tod, "Alphabetic") used in scientific texts is decimal but not positional, that number "zero" does not exist (but a sign for the "empty place" was currently used), and that the numbers from 1 to 999 are denoted by the 24 current alphabetical letters plus three additional signs, namely, letters ϛ (*digamma*, that in Byzantine manuscripts and in modern editions is always represented by the *sigma-tau* ligature known as *stigma*, almost identical to a form of *digamma* itself), ϙ (*koppa*), and ϡ (*sampi*). These 27 letters are divided in three groups of nine, denoting in succession the

gers of the hands; definition of the five elementary arithmetic operations on integers (extraction of an approximate square root included); denominations of numerical orders and their multiplication; tables (see below). Greek numerals are used. No calculations are worked out: the adduced paradigmatic examples simply amount to providing the operands and the result of the operation, and to check that they fit the definition.

– Rhabdas, *Letter to Tzavoukhes*.[54] It contains: multiplication and division (by reduction) of unit fractions; two methods of extraction of an approximate square root, the one a refinement of the other; an Easter Computus, assuming a.m. 6849 = 1341 as current year; the so-called μέθοδος πολιτικῶν λογαρισμῶν *Procedure of civil life computations*, namely, an exposition of the several species of the rule of three; generalities and some problems involving weights, measures, and currency units, solved by application of the previous rules; the same for a problem involving blending; twenty *Rechenbuch*-style problems, with solutions and associated procedures.[55] Greek numerals are used.
– *Anonymi* SG, two short theoretical texts about operations on unit fractions in Par. suppl. gr. 387, fols. 62v–63r, and 157r–158r.[56]
– Metochites, a computational primer to the *Almagest*, which makes the whole of Book II of his *Abridged Astronomical Elements*.[57]
– John Catrarios (*c*. 1310–20; *PLP* 11544), an autograph scholium in Vat. gr. 184 (2nd half of 13th century), fols. 80v–81r, expounding the basics of the sexagesimal system.

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units from 1 to 9, the tens from 10 to 90, and the hundreds from 100 to 900. As said, specific signs are added to the same digits to denote higher numerical orders. Thus, ͵δχκθ is 4629. See note 73 below for Prodromenos' and Sgouros' flawed notation.

54 Edition Tannery, "Notice," pp. 118–86. See also Tannery, "Manuel Moschopoulos et Nicolas Rhabdas" for a summary description of the contents. On the Easter Computus see Schissel, "Osterrechnung."

55 Some of these coincide with problems in the *Rechenbuch* I shall call *Anonymus* P: no. 13 ed. Vogel = example at Tannery, "Notice," pp. 142.26–144.9; no. 14 = Rhabdas' problem I; 18 = problem III; 20 = IV; 21 = VI; 22 = VII; 9 = X; 11 = XII; 24 = XIII; 35 = XVI. Algebraic formulations of the problems in this section are in Tannery, "Manuel Moschopoulos et Nicolas Rhabdas," p. 14. The entire μέθοδος πολιτικῶν λογαρισμῶν is in fact a *Rechenbuch*, as we shall see presently. The title returns in the phrases at Tannery, "Notice," 140.8 and 154.3–4.

56 The former is edited in Hero, *Opera omnia*, vol. 4, ed. Heiberg, pp. xiv–xv; see also below for the latter.

57 Edition of Book II, sections 1–5, by Derycke. The section on square root is copied as an extract in Vat. gr. 193, fols. 166r–167v (15th century); it is followed by a reworked excerpt of the section on square root in Rhabdas' *Letter to Khatzykes* (Tannery, "Notice," pp. 100.13–102.7).

- Prodromenos, an autograph scholium in Par. gr. 1928, fol. 15r, on a specific numerical notation with "Indian" numerals, in this case of the Eastern Arabic type.[58] Zero is not used; tens, hundreds, etc. are noted by superimposing a suitable number of small circles above the figures for units.[59]
- Argyros, a treatise on the extraction of an approximate square root.[60] Three methods are expounded, the second a refinement of the first, the third involving linear interpolation between the values of approximate square roots of integers set out in a table. Calculations are performed both with unit fractions and within the sexagesimal system; Greek numerals are used. As for other sources on approximate square roots, a method is also expounded in a text that the editor has attached to Barlaam's *Logistic*, but which is a later complement to it.[61] A method by linear interpolation different from Argyros' can be found in the *Rechenbuch* I shall call *Anonymus* 1436, no. 123; the latter coincides with a prescription we read in the hand of George Gemistos Plethon (see below). Two scholia with methods for calculating an approximate square root will be mentioned below, among the Diophantine fakes.[62] Contrary to what is implied by modern literature on the subject, *all* methods just listed, the ones by interpolation excepted, as well as those by Planudes and Rhabdas mentioned above, amount to the standard, first- or second-order Heronian approximation. Algebraic transcriptions may be deceiving.
- Meliteniotes, a computational primer to the *Almagest* in the initial segment of Book I of his *Three Books on Astronomy*.[63]
- *Anonymus* M (end 14th century), a computational primer to the *Almagest* by and large made of extracts from the logistic portion of Pachymeres' *Quadrivium* and from Metochites' and Meliteniotes' primers.[64]

58 Edition Tannery, "Scholie."

59 Two short tabular texts on numerical notation adopting this convention are in Marc. gr. 323, fol. 487r–v (early 15th century); they are edited in Heiberg, "Analekten," pp. 172–74. Of course, this notation amounts to not understanding that Hindu-Arabic numerals must be used positionally. The notation is inspired by the notation for higher numerical orders expounded in the source of Rhabdas' *Letter to Khatzykes*.

60 Edition Allard, "Petit traité."

61 Edition Barlaam, *Logistic*, p. 114. This is at least contained in Ambros. E 76 sup. (an edition of his own writings "authorised" by Barlaam), fol. 110r, and in its 16th-century apographs Ambros. P 72 sup., fol. 59r–v, and R 117 sup., fols. 152v–153r.

62 A further text, appended to Proclus' *Outline*, is published in Heiberg, "Kleine Anecdota," p. 164 (the right location is however fol. 145v of Laur. Plut. 28.7 [2nd half of 14th century]). All methods amount to the standard first-order Heronian approximation.

63 Edition Meliteniotes, *Three Books on Astronomy*, pp. 92–154.

64 Edition *Anonymus* M.

- *Anonymus* A (14th century), a text expounding, in general terms and on the basis of a paradigmatic example, a method for multiplying integer numbers.[65] The numerals have the same form as in Planudes' *Great calculation*.
- *Anonymus* PS (15th century), a text expounding in general terms two methods for multiplying integer numbers.[66] No numerals are used.
- Chortasmenos, an autograph scholium in Modena, Biblioteca Estense Universitaria, α.T.8.21, fol. 26r–v, on calculating an approximate square root by means of *Elements* II.4 (this is a standard method, as we have seen).
- The *Rechenbücher Anonymus* 1436, *Anonymus* U, and *Anonymus* V (the first and the third are contained in the same manuscript, as we shall see) present methods for calculating with fractions: nos. 21, 22, 90–110 of *Anonymus* 1436, 37–52 of *Anonymus* V, and the last six items of *Anonymus* U. *Anonymus* 1436 includes a fragmented handbook of logistic featuring: notational issues, including the sign for zero (nos. 1–5); multiplication (with an example assuming 1436 as current year) and division of integers (6–39); operations with fractions (40–52); extraction of an approximate square root by linear interpolation (123; different from Argyros'); extraction of cube roots (118); calculations with roots (119–133). The manuscript containing *Anonymi* 1436 and V features, in the margins and within the text but always in the hand of the main copyist, hundreds of carried-out arithmetic operations.
- Plethon, two short texts: on the extraction of an approximate square root by linear interpolation (different from Argyros,' but identical with that in *Anonymus* 1436); on compounded ratios, removal of a ratio from a ratio, and taking of a fourth proportional.[67]
- George of Trebizond (d. *c.* 1472–73), Εἰσαγωγὴ εἰς τὴν μεγάλην τοῦ Πτολεμαίου Σύνταξιν *Introduction to Ptolemy's Almagest*. This must be regarded as the best computational primer to the *Almagest*. George wrote two versions of the treatise, one in Latin (written in 1452; it is the introductory portion of his gigantic *Commentary on the Almagest*) and the other in Greek, in 1465/66 on his way to Istanbul and with the aim of offering it as a gift to Mehmed II (d. 3/5/1481).[68] The Greek and the Latin versions, allegedly one the translation of the other, are instead very different.

65 Edition, translation, and commentary in Allard, "Procédés," pp. 119–34; source Laur. Ashburnham 1599, additional folios inserted between fols. 159/160 and 163/164. The procedure, accompanied by a tabular set-out, is the so-called "gelosia" method.

66 Edition, translation, and commentary *ibidem*, pp. 134–43; source Par. suppl. gr. 652, fol. 148r. The second procedure is the so-called "gelosia" method; it is not accompanied by any tabular set-out.

67 These are Text 2 and Text 3 in Acerbi/Martinelli Tempesta/Vitrac, "Interventi autografi."

68 Short description in Monfasani, *Collectanea*, pp. 687–88; edition forthcoming in Acerbi,

– Sets of numerical tables were composed to assist calculations. A 60×60 multiplication table of first minutes times first minutes is contained in a number of manuscripts; its diffusion is explained by the fact that it was part of the so-called *Persian Tables*;[69] it may be accompanied by short instructions of use.[70] Trigonometric tables are also included in specific collections of persian tables.[71] A very structured set of tables of addition, subtraction, multiplication, and partition of integer numbers is found at the end of Rhabdas' *Letter to Khatzykes*;[72] similar tables make the Ψηφάριον *Counting book* comprising the entire Vat. gr. 1550 (14th century).[73] Standard multiplication tables can be found in Vindob. phil. gr 65, fols. 67v–73r (= *Anonymus* 1436, no. 127); fols. 118r–123v of the same manuscript contain tables of square roots, empty for the most part. As mentioned above, Argyros' treatise on the extraction of a square root contains a table with square roots (approximated to third minutes) of the integers up to 102. A square roots table, whose

*Logistic Texts*; the text in München, Bayerische Staatsbibliothek, gr. 537, fols. 37r–66r, carries autograph corrections. On George's commentary see Monfasani, *Collectanea*, pp. 671–87.

69 On this medieval update of Ptolemy's *Handy Tables*, see Tihon, "Tables."

70 See Ambros. E 80 sup., fols. 157r–164r (middle 15th); Laur. Plut. 28.1, fols. 339v–340r (1st half of 14th century); Laur. Plut. 28.13, fols. 81r–90v (*c.* 1374); Laur. Plut. 28.16, fols. 88r–97v (1382); Marc. gr. 323, 152v–159v; Marc. gr. 326, fols. 69r–76r (middle 15th century); Marc. gr. 327, fols. 161r–168r (middle 15th); Marc. gr. 328, fols. 117r–120v (early 15th); Marc. gr. 333, fols. 256r–263r (Bessarion's autograph); Marc. gr. 336, fols. 107r–116v (end 14th–beginning 15th); Par. gr. 2501, fols. 59r–66r (1st half of 15th); Vat. Pal. gr. 278, fols. 89r–96r (1st half of 15th); Vat. gr. 191, fols. 317v–318v (last quarter of 13th); Vat. gr. 792, fols. 22r–23v (here early 15th); Vat. gr. 1047, fols. 113ar–120r (1st half of 15th); Vat. gr. 1058, fols. 439r–440v (here middle 14th). Edition in Chioniades, *Works*, ed. Pingree, vol. 2, pp. 225–35.

71 See for instance Vat. gr. 1058, fols. 431v–433r, and Vat. gr. 210, fols. 232v–234r (same copyist). Edition in Chioniades, *Works*, ed. Pingree, vol. 2, pp. 197–201.

72 They are said to be εὕρεμα Παλαμήδους "Palamedes' discovery"; they were only partly edited by Tannery.

73 The latter are edited in Heiberg, "Kleine Anecdota," pp. 165–70. Similar tables, with instructions of use partly identical with those in Rhabdas' *Letter to Khatzykes*, can be found in Marc. gr. 323, fols. 25r–37v, and Vat. gr. 1058, fols. 33r–40r (same copyist, here early 15th). Standard multiplication tables, ascribed to Andronikos Doukas Sgouros (*PLP* 25048), can be found in Ambros. E 80 sup., fols. 179r–195r (see also Vat. gr. 1058, fols. 41r–52v, without the ascription); they are affected by a systematic notational mistake (the author did not realize that a myriad of myriads coincides with ten-times-thousand myriads), run as far as $10^9 \times 10^9$, and are followed (fols. 195v–196r) by a tabular set-up of the names of the numbers associated to each numerical sign. In Sgouros' notation, myriads are denoted by a superimposed trema, myriads of myriads by a single superimposed dot. A partition of the 24 letters of the Greek alphabet according to their numerical values is presented in Par. suppl. gr. 920, fol. 1r–v (10th): Acerbi, "How to Spell."

values are also provided in the sexagesimal system and are approximated to second minutes, is also found in Heidelb. Pal. gr. 129 (mainly 14th century), fols. 11v–12r. According to the inscription, the table was calculated by Rhabdas and dedicated to Gregoras; it ranges from 1 to 120 but its second half is empty.[74] Tabular set-ups of Eratosthenes' sieve for prime numbers are found for instance in Par. suppl. gr. 387, fol. 151v, and Vat. Ottob. gr. 80, fols. 135v/142r (the latter is one of Chortasmenos' notebooks). An "arithmetical triangle" (in combinatorial sense) of unknown origin is presented as a scholium in Vat. gr. 1038, fol. 129v (end 13th century).[75]

To find a rationale in the farrago of *Rechenbücher* is a difficult task. Already the definition of the genre gives rise to problems.[76] We may say that these are collections of computational techniques and of arithmetical or geometric metrological problems unrelated to each other, sometimes in (fictitious) daily-life guise,[77] and often formulated in a debased algorithmic code. As a matter of fact, the "mathematical content" of typical *Rechenbuch*-problems is frequently related more to number theory than to logistic:[78] some of them can be undressed and rewritten as Diophantine problems—that is, as algebraic equations. Still, the stylistic code of reference adopted in such collections and the fact that several problems cannot be rewritten as Diophantine problems suggest categorizing them within logistic. A genre with partly similar characteristics is that of arithmetical riddles in form of epigrams, collected in part of Book XIV of the *Palatine Anthology*.[79] Add to this a florilegium of geometric

74 See Biedl, "Heidelberger," 104–6.

75 Edition Euclid, *Opera omnia*, vol. 8, ed. Heiberg, pp. 290–91; analysis in Acerbi, "Shoulders," pp. 483–86. I now believe that its origin does not date back to ancient Greece.

76 The German denomination comes from Latin *liber abbaci*, whose eponymous specimen is Fibonacci's (at least two versions, the later one written in 1228).

77 I put "fictitious" in inverted commas since some kinds of problem do answer to practical exigencies, like those on the calculation of interest or on the conversion of units of measurement (currency, weight, capacity). I use "problem" in the wide sense of a short, self-contained mathematical unit (explicitly or implicitly) proposing a series of operations devised to answer a specific question.

78 If any such "typical" texts exist: the 100 problems in *Anonymus* V are distributed by the editors among 32 categories. To make categorizations of genres even more complex, recall that, in the doctrinal framework of the Neoplatonic author of isagogic *prolegomena* to Nikomachus' *Introduction to arithmetic*, the difference between number theory (Nikomachus) and arithmetical zetetic (Diophantos) lies in the polarity ἀριθμὸς μετρῶν / μετρούμενος "measuring / measured number" (Diophantos, *Opera omnia*, ed. Tannery, vol. 2, pp. 73.20–74.2).

79 Scholia to some of these epigrams, presenting solutions of them, are edited in Diophantos, *Opera omnia*, ed. Tannery, vol. 2, pp. 43–72, drawing from Par. suppl. gr. 384 (early–middle 10th century). On the structure of the collection see Tannery, "Épigrammes."

metrological problems, some of which are in fact problems of Diophantine analysis in fictitious metrological guise (problems "of separation"), contained in Istanbul, Topkapı Sarayı Müzesi G.İ.1 (written *c.* 960), fols. 28v–38v.[80] The *Rechenbücher* I know of are given in the following list.[81]

- *Anonymus* 1183, Par. gr. 1670, fols. 21v–61v.[82] This is something like a *Ur-Rechenbuch*, namely, a collection of apparently disconnected subsets of problems. It contains: fols. 21v–34v, multiples and submultiples of currency units;[83] 35r–46v, division procedures described above; 46v–61v, Easter Computus, repeatedly assuming 1183 as current year; 61v, measure of a stone solid. Greek numerals are of course used. The final part of the manuscript (fols. 62r–130v) contains geometric metrological material.[84]
- *Anonymus* 1256, Vat. Pal. gr. 367, fols. 69r–98r.[85] Written in vernacular Greek. Contents include: fols. 69r–83v, title μέθοδοι σὺν θεῷ λογαρικοὶ ὡς ἐν ἐπιτόμῳ πάνυ ὠφέλιμοι τοῖς νουνεχῶς προσέχουσιν αὐτοὺς νέοις *Abridged computational procedures very useful for the young people carefully attending them*, 109 items featuring standard riddles, applications of the rule of three, and Diophantine-style problems in everyday-life guise, problems of conversion involving weight, length, and currency units of measurement, calculations with fractions; 83v–84r, a table of decomposition of common fractions into unit fractions, set out as usual as division of numbers 1 … *n* by *n*, with *n* = 6 … 17; 84v–88v, a general procedure for an Easter Computus, assuming a.m. 6764 = 1256 as current year; it is preceded by a standard Damascene

80 See Heiberg/Zeuthen, "Aufgaben," and Hero, *Metrica*, ed. Acerbi/Vitrac, pp. 492–97.

81 On the phenomenon of *Rechenbuch*-style problems attached to logistic treatises, see the paragraph on Diophantine fakes on p. 134 below and Acerbi, "Problemi."

82 The manuscript is described in Hero, *Opera omnia*, vol. 4, ed. Heiberg, pp. x–xi (with edition of the text at fol. 61v *ibidem*, p. xvii); Hero, *Metrica*, ed. Acerbi/Vitrac, pp. 436–37. *Editio princeps* of fols. 3r–21v in Montfaucon, *Analecta*, pp. 316–92; Montfaucon also used this material for the chapters on technical abbreviations in his celebrated *Palaeographia Graeca*, pp. 359–373. These folia of Par. gr. 1670 contain the fiscal treatises known as *Palaia Logarikê* (fols. 3r–13r) and *Nea Logarikê* (13r–21v), composed shortly after the death of Alexios I Komnenos in 1118; most accessible edition in Lingenthal, *Jus*, pp. 385–400 (resorting to a tabular set-up that destroys the original layout); commentaries in Hendy, *Coinage*, pp. 50–64, and Morrisson, "Logarikè" (with complete French translation). Edition of *Anomymi* 1183, 1256, 1306, and R in Acerbi, *Logistic Texts*; of *Anonymi* J and L, and of the table of decomposition of common fractions into unit fractions in *Anonymus* 1183, in Acerbi, "Rechenbücher."

83 Titles ἀρχὴ σὺν θεῷ τῶν λιτρισμῶν *Beginning, with God, of the measures by pounds*, and περὶ τῶν λεπτῶν τῆς λίτρας *On the parts of the pound*, at fols. 21v–33v and 33v–34v, respectively.

84 Edited in Hero, *Opera omnia*, vol. 4, ed. Heiberg.

85 Analysis of the manuscript, inclusive of the several datings occurring in it, in Turyn, *Codices*, pp. 117–24 and pl. 96.

Easter table; 88v–92v, capacity of ships and measurement of quantities of specific goods like oil, wine, and salt; 92v–93v, two testament templates; 94r–98r, geometric metrological problems.[86] Greek numerals are used.

- *Anonymus* E, El Escorial, Real Biblioteca del Monasterio de S. Lorenzo, X.IV.5, gr. 400 (13th century); 259 items (entire manuscript). In Cypriot vernacular language. It has never been studied; my own partial inspection suggests that the effort of editing it might be not entirely repaid by the outcome.
- *Anonymus* L, Firenze, Biblioteca Medicea Laurenziana, Pluteus 86.3 (2nd half of 13th century), fols. 165r–169v; 48 items partitioned into subsections, partly overlapping (24 items), although with substantial variants, with *Anonymus* P. Greek numerals are used.
- *Anonymus* J. Vat. gr. 191, fol. 261r (2nd half of 13th century); 6 items, title ἀρχὴ σὺν θεῷ τῶν διαφόρων ἐρωτημάτων. This single page, deleted by pen strokes, is embedded into an astrological collection: the bifolio where these problems belong was there used as recycled paper.
- *Anonymus* P, Par. suppl. gr. 387 (end 13th century), fols. 118v–140v; 119 items, title Ψηφηφορικὰ ζητήματα καὶ προβλήματα, ἃ δὴ καὶ μετὰ τῶν οἰκείων μεθόδων ἕκαστον σύγκειται *Calculative investigations and problems, which are collected here each with its own procedures, too*.[87] It also contains some geometric metrological problems and number-theoretical elaborations. The distribution of the problems among categories is random. Greek numerals are used. Most of what precedes in the manuscript is isagogic or geometric metrological material.[88]
- *Anonymus* 1306, Par. suppl. gr. 387 (early 14th century), fols. 148r–161v. This is also something like a *Ur-Rechenbuch*. It features: fols. 148r–149v, operations on fractions; 149v, Easter Computus to a.m. 6814 = 1306; 150r–151r, very short annotations (one of which dated 1303), followed by one *Rechenbuch*-style

86 These problems, as well as a short text at fol. 80v, are edited in Schilbach, *Quellen*, sects. I.5c–d, II.4, 14, 16, 18, III.1, 2e,k, IV.4d, 8b,f; see also *ibidem*, p. 13. The two testament templates are edited in Ferrari, "Due formule."

87 Edition *Anonymus* P. The manuscript is described in Hero, *Opera omnia*, vol. 4, ed. Heiberg, pp. iv–vii; Concasty, "Manuscrit scolaire"; Hero, *Metrica*, ed. Acerbi/Vitrac, pp. 437–39. *Anonymus* 1306 is in a hand different from (and later than) that of *Anonymus* P (A. Gioffreda, *per litteras*). Thus it is incorrect to assign the date of the former to the latter.

88 Edited in Hero, *Opera omnia*, vols. 4–5, ed. Heiberg. The isagogic material are the pseudo-Heronian *Definitiones*. Fols. 141r–147v contain extracts from the arithmetical section of *Anonymus* 1007 (sects. 5–8, pp. 52.3–54.6, 10–12, pp. 54.23–55.1, 55.10–15, 55.17–24, and 21, p. 62.12–19, the latter in a later hand—but Heiberg did not use this manuscript) and (at fols. 142v–147r) a description of a cosmological system.

problem; 151v, Eratosthenes' sieve; 152r–v, calculation of currency interests, title ἑτέρα ψηφιφορία περί τε τόκων νομισμάτων διαφορᾶς τε καὶ φυρασίας, καὶ ἔστιν εἰπεῖν οὕτως περὶ τόκων νομισμάτων *Calculation about the difference and combination of interests of nomismata, which amounts to say about interests of nomismata*; 152v–157r, basic applications of the rule of three, title ἑτέρα μέθοδος ἀριθμητικὴ περὶ κέρδους καὶ ζημίας *Another arithmetical procedure about profit and loss*; 157r–158r, calculation with unit fractions, title ψηφιφορία περὶ συνθέσεως μορίων ἐκβολῆς διαιρέσεώς τε καὶ πολλαπλασιασμοῦ *Calculation about addition, subtraction, division and multiplication of parts*; 158r–161v, three sets of typical *Rechenbuch*-style problems: first set, 8 items, no title; second set, 4 items, title ψηφιφορικὰ προβλήματα πάνυ ὀφέλημα *Very useful calculative problems*;[89] second set, 6 items, title μέθοδοι καθολικαί *General procedures*.

- The μέθοδος πολιτικῶν λογαρισμῶν *Procedure of civil life computations* in Rhabdas' *Letter to Tzavoukhes*, described above.
- *Anonymus* 1436, Vindob. phil. gr. 65, fols. 11r–126r; 242 numbered items.[90] In two books, written in vernacular Greek, with obvious lexical loans from Italian and Arabic-Turkish. Apart from the fragmented handbook of logistic described above,[91] it contains; rule of three and arithmetical problems (nos. 53–116, 153–165), sometimes without the daily-life guise (134–152),[92] including the sum of arithmetic progressions (57–60; see below); geometrical problems solved numerically and metrological problems (166–242). *Anonymi* 1436 and V only use Greek numerals, with an additional figure for the zero; sometimes, the Greek numeral signs from α to θ are also used to designate tens, hundreds, etc.: the resulting notation is positional.

89 The first three items of this subset coincide with the first three in the *Anonymus* L, the first two also coincide with nos. 62 and 63 of *Anonymus* P. Later in the manuscript, fols. 181v–208r contain a substantial collection of problems on conversion of units of measurement, a lore a title dubs νοταρικὴ ἐπιστήμη "notarial knowledge."

90 Editions *Anonymus* 1436. Other texts pertaining to the logistic part of this item are found on fols. 4v–5v, 6r–9v and 142v–159v of the manuscript; the latter mainly repeat sections of *Anonymus* 1436.

91 Note that nos. 185–200 are missing because a page was lost in some ancestor of Vindob. phil. gr. 65 (which does not show traces of a missing page); their content (mainly rules for fortification-building) can be recovered from the initial table of contents (fol. 13r–v); no. 117 is the preface to Book II.

92 Thus, these are algebraic problems in Diophantine style and worded in the typical Middle-Age fashion (the unknown is called πρᾶγμα, etc.). This feature is unique to *Anonymus* 1436.

– *Anonymus* V, again Vindob. phil. gr. 65 (15th century), fols. 126v–140r; 100 numbered items.[93] Written in vernacular Greek, with obvious lexical loans from Italian and Arabic-Turkish. It also contains few computational methods and some geometric metrological problems.
– *Anonymus* R, Firenze, Biblioteca Riccardiana, gr. 12, fols. 26v–27r (1430–50); 6 items.[94]
– *Anonymus* U, Uppsala, Universitetsbibliotek, gr. 8 (late 15th century), fols. 324r–331r; 18 items.[95] Written in vernacular Greek, with obvious lexical loans from Italian. Twelve problems are followed by six exercises on multiplication and division of fractions. Both Greek and Western Arabic numerals are used.

The descriptions of some of the above items show that the designation *Rechenbuch* must be taken to refer to a constellation of more or less well-structured, highly sectional, logistic collections; these can sometimes prove difficult to delimit in a given manuscript, because of the simultaneous presence, in the manuscripts, of strictly geometric metrological material that we might wish to attach to a given *Rechenbuch* or not. The existence of what I have called *Ur-Rechenbücher* adds a diachronical dimension to the issue. In particular, problems in fictitious daily-life guise seem to enter the corpus during the Nicaean period (1204–61).

93 Edition *Anonymus* V; the copyist is not the same as that of *Anonymus* 1436. The manuscript was first described, with edition of some extracts, in Heiberg, "Analekten," pp. 163–69; among these extracts (fols. 146v–147r) features a numerical list of powers of 2 as far as $2^{63}$, with three additional texts (a rule for getting the sum as far as an arbitrary power, a rule for multiplying specific powers, a note on some peculiar denominations of higher numerical orders; only the latter is edited by Heiberg): this is the so-called "wheat and chessboard problem"; the same copyist transcribed the list and two of the three texts in Ambros. I 112 sup., fols. IIIv–IVr; a chessboard scheme in whose cells the same numbers are marked is in Ambros. E 80 sup., fol. 196v (the last two cells are empty). A problem identical with *Anonymus* V, no. 38, is edited in Spingou, "Πῶς δεῖ εὑρίσκειν," but the editor did not understand the mathematics underlying the problem.

94 The second in order coincides with the one edited in Nikomachos, *Introduction*, pp. 152.5–153.6, the third with the one included in Rhabdas' *Letter to Tzavoukhes* and edited in Tannery, "Notice," pp. 184.20–186.4. All the problems were penned by George Scholarios (d. *c.* 1472; *PLP* 27304—I thank D. Speranzi, who communicated to me the description of the manuscript in his forthcoming catalogue of the Greek manuscripts of the Riccardiana library).

95 Edition *Anonymus* U.

## 4 Arithmetic

Arithmetic deals with abstract properties of integer numbers and is formulated in demonstrative or procedural style; its proofs are often illustrated by line diagrams.[96] Arithmetic coincides with our number theory. Ancient Greek paradigms of this discipline are Euclid's *Elements*, Books VII–IX (demonstrative code), and Nikomachos' *Introduction* (procedural code embedded in a discursive frame). In arithmetic, the mathematical facts established by means of a proof may give rise to operative prescriptions formulated in procedural or algorithmic code.[97] As said above, a key treatise as Diophantos' *Arithmetics*, which contains arithmetical problems solved using the demonstrative code but possibly dealing with non-integer numbers, was considered as belonging to logistic. Nevertheless, it will be treated in the present section.

I shall first present traces of activity on Nikomachos' and Diophantos' treatises. If we exclude the excerpts contained in the *Quadrivia* described above, the *Elements* was usually handled as a whole, and its author regarded as the chief authority of geometry.

Nikomachos is regularly mentioned in the standard accounts of teaching activities in Byzantium; it is therefore no surprise that his *Introduction* has been handed down in about ninety manuscripts. Actually, most of these manuscripts contain recensions of the Greek text, possibly contaminated with each other; in absence of a critical edition of Nikomachos' treatise,[98] however, nothing can be said as to the Byzantine origin of any of these recensions. The earliest codex containing the *Introduction* is Madrid, Biblioteca Nacional, 4678, written by two hands dated to about 1060–80. Marginal annotations in this codex amount to a running commentary, penned by the main copyist, and by scholia of two scholarly hands of end 12th and end 13th century; the second of them, featuring only in a restoration dated 1260–80, resembles that of Gregory of Cypros.[99]

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96 The diagrams in Medieval manuscripts are usually more symmetric than the geometric configurations they are intended to represent; this phenomenon is called "overspecification." I proposed an explanation, based on phenomena well-known in pattern-reproduction psychology, in Acerbi, "Mathematical Scholia," pp. 244–46, which also see for previous bibliography.

97 The best example of the former is in Diophantos' *On polygonal numbers*.

98 Edition Nikomachos, *Introduction*; see also Haase, *Untersuchungen*. The scholia on Nikomachos are a *mare magnum* and have never been studied.

99 On all features of the Madrid codex see Pérez Martín, "Maxime Planude." An interesting document on the circulation of scientific manuscripts in this period is the loan list in Vat. gr. 207, fol. VIIIr: the anonymous copyist-scholar (a functionary of the Patriarchate) lent three of his exemplars of an ἀριθμητική (maybe Nikomachos?) and one of a μουσική to

Since Nikomachos and Euclid are regularly mentioned together in contemporary sources on teaching curricula, one might expect to find early isagogic codices in which these two authors were transcribed together. However, a survey made in the standard databases shows that this is not the case: no such manuscripts are extant before the 14th century.[100]

Other traces of activity on Nikomachos include the following.

- Three scholia in Ambros. G 62 sup., fols. 65v–66v, two of them ascribed to the renowned scholars ⟨Michael⟩ of Ephesos and Eustratios of Nicaea (both *c.* 1100), the third to a certain judge Nicholas Dishypatos.[101] They all deal with the prescription allowing the generation of all kinds of ratios from that of equality (*Introduction* I.23.15). A scholium on the same section is ascribed in some manuscripts to a Demetrios Protocensor.
- The excerpts in Pachymeres' *Quadrivium*, for which see above.
- A tract, explicitly presented as a complement to Nikomachos, written by the Aristotelian commentator Leo Magentinos (1st half of 14th century; *PLP* 16027) and entitled Περὶ τοῦ πῶς ἐστιν ὁ δέκα τέλειος ἀριθμός *On why ten is a perfect number*; I have only found it in Vindob. phil. gr. 65, fol. 4r–v.[102]
- At least two scholia attributed to Gregoras in a number of manuscripts of the so-called *recensio* II of Philoponos' commentary on the *Introduction*.
- Some scholia attributed to Argyros, more or less in the same manuscripts as Gregoras'.[103] Tannery ascribed *recensio* II of Philoponos' commentary to Argyros himself.[104]

The traces of activity on Diophantos' *Arithmetics* deserve a more extended discussion. In a letter to an anonymous addressee,[105] Michael Psellos explains

well-known personalities (see Canart, "A propos," pp. 279–283; the loan lists covers a period from 12/11/1268 to 18/08/1282).

100 These are: Vat. Ottob. gr. 310 (15th century), Vat. gr. 196 (14th) and 1709 (early 15th); Mutin. α.U.9.7 (14th); Par. Coisl. 174 (14th–15th), Par. gr. 2373 (14th), 2481 (15th), 2531 (15th), 2762 (early 15th); Marc. gr. 309 and 317 (composite, both middle 14th); Vindob. phil. gr. 62 (2nd half of 15th).

101 These scholia are mentioned in Tannery, "Rapport," p. 329, and recorded in the Martini-Bassi catalogue.

102 Related material can be found at fols. 1v–2v and 5v–6r of the same manuscript (one text is transcribed twice, the former being the better version).

103 Edition of Gregoras' and Argyros' scholia in Acerbi, "Problemi," Text 21.

104 Tannery, "Rapport," pp. 302–10.

105 The letter was first partly published in Tannery, "Psellos sur Diophante," and in its complete form in Diophantos, *Opera omnia*, ed. Tannery, pp. 37.3–42.13: see pp. 37.3–39.10 for the part pertaining to number theory (thoroughly discussed in Acerbi, "Unaccountable," pp. 910–16, which I summarize here); pp. 39.11–41.21 for the metrological issues; arithmology (for which see below) is liquidated at pp. 41.22–42.13. See also Moore, *Iter Psellianum*, PHI.158.

some basic notions and tools of number theory and geometric metrology: these are the denominations of the numerical species according to Diophantos[106] and their usefulness in solving arithmetic riddles in form of epigrams; how to measure some simple solids. As Psellos himself appears to declare, he resorted to the popularization of Diophantos' notation written by the λογιώτατος "most learned" Anatolios, maybe to be identified with the person whose name is attached to a treatise on the Decad, a *specimen* of the arithmological sub-genre *Theology of Arithmetic*.[107] The numerical denominations are extended to higher species than in the *Arithmetics*, where the last species introduced is the κυβόκυβος, namely, the 6-species. Psellos goes as far as the 9-species, even if for the inverse species he stops, exactly as Diophantos did, at the κυβοκυβοστόν. All species are given alternative names, according to their rank: ἀριθμός = ἀριθμὸς πρῶτος, δύναμις = ἀριθμὸς δεύτερος, …; again, some species starting from the fifth are given further alternative names: 5-species (= δυναμόκυβος = ἀριθμὸς πέμπτος) = ἄλογος πρῶτος "first irrational"; 7-species (= ἀριθμὸς ἕβδομος) = ἄλογος δεύτερος "second irrational," 8-species = τετραπλῆ δύναμις "fourfold power," 9-species = κύβος ἐξελικτός "revolved cube." The system expounded by Psellos appears to be a descriptive-classificatory attempt conflating notions and terminology that come from several sources. The idea of adopting the rank within a well-ordered sequence of (mathematical) objects to the effect of creating a "logarithmic" system of denominations (ἀριθμὸς πρῶτος, ἀριθμὸς δεύτερος, …) coincides with that exploited by Archimedes in the *Sand-Reckoner* to give names to the several orders of magnitude in the decimal system: and in fact, the denominations are identical with those introduced by Archimedes. As for the other denominations, the micro-system of ἄλογοι included, the likely identification of Psellos' Anatolios with the author of the tract on the Decad might suggest a Neo-Pythagorean origin, even if the lexicon employed does not specially recommend this option: no occurrence of ἄλογος in a similar sense and in technical contexts can be found in the writings of Nikomachos or of Iamblichos.

Overlapping with Psellos' lifespan is the earliest, and certainly the most authoritative, witness of Diophantos' *Arithmetics*, namely, Matrit. 4678. Marginal annotations in this codex consist of those written by the main copyists (not a running commentary, as in the case of Nikomachus in the same manuscript) and of the scholia apposed by three scholarly hands. The first is a "wild cursive"

106 In my discussion below, an *n*-species corresponds to our *n*th power.

107 A good introduction to the several Anatolios living around in the 3rd century, written by R. Goulet, can be found in Goulet ed., *Dictionnaire*, vol. 1, pp. 179–83; the edition of the arithmological tract ascribed to one Anatolios (amply excerpted in the pseudo-Iamblichean *Theology of Arithmetic*) is in Heiberg, "Anatolius."

of end 12th—beginning 13th century, the second is the hand of Planudes, the third that of Chortasmenos.[108] Two letters by Planudes allow us to reconstruct a part of the history of the *Matritensis*, and to establish that in Planudes' time there were three exemplars of the *Arithmetics* circulating in Constantinople. In *Letter* 33, Planudes asks his addressee, Manuel Bryennios, to send him his copy for checking his own; in *Letter* 67, he communicates to the *protosebastes* Theodore Mouzalon (d. 3/1294; *PLP* 19439) that he is sending him back his exemplar in a better state than when he received it.[109] Thus, Planudes restored Mouzalon's codex, a fact that fits quite well the present condition of the *Matritensis*.[110] Planudes also wrote a running commentary on Books I–II of the *Arithmetics*,[111] partly extant in the autograph Ambros. & 157 sup., and in complete form in the direct, and immediately subsequent, apograph Marc. gr. 308, fols. 50–284 (the codex is a composite). The commentary contains rephrasings and schematic tabular representations of Diophantos' solutions, explanations and geometrical interpretations.

Pachymeres' use of Diophantos in his *Quadrivium* is also worthy of discussion. As mentioned above, Diophantine material ranges over §§ 25–44 of section I. § 25 deals at length with numerical species and inverse species. The subsequent sections correspond to problems in the *Arithmetics* as follows. § 26 = *Ar.* I.1; §§ 27–32 = *Ar.* I.2 (to divide a given number in a given ratio), the multiplicity of chapters coming from the fact that Pachymeres amply exemplifies in each of them one of the basic five categories of ratios;[112] §§ 33–35 = *Ar.* I.3, again with all five categories; §§ 36–38 have no correlate; the problem is to divide a given number falling short of another given number in a given ratio[113]; § 39 = *Ar.* I.4, only for multiple ratios; § 40 = *Ar.* I.5 and 6, only for simple parts; § 41 = *Ar.* I.8, only for multiple ratios; § 42 = *Ar.* I.9 (to subtract the same number from two given numbers so that the results are in a given ratio), just one specific multiple but several instances of the difference; § 43 = *Ar.* I.9, with coupled instances of multiples and differences; § 44 = *Ar.* I.10 and 11. In every

108 Most of these scholia are edited in Allard, "Scholies."

109 Planudes, *Letters* 33 and 67, ed. Leone, pp. 66.13–17 and 99.24–29, respectively. Mouzalon's exemplar, however, might coincide with the one in Planudes' hands mentioned in his *Letter* 33.

110 See Pérez Martín, "Maxime Planude." Planudes' description of the restored manuscript in his *Letter* 67, ed. Leone, p. 100.7–12, also leaves no doubt as to the fact that the codex he mentions is the *Matritensis*.

111 Edition Diophantos, *Opera omnia*, ed. Tannery, vol. 2, pp. 125–255.

112 These are: multiple, superparticular, superpartient, multiple-superparticular (§§ 30–1), multiple-superpartient.

113 This problems reduces of course to *Ar.* I.2. All five categories of ratios are again taken into account.

case, Pachymeres gives several examples and formulates a general rule of solution (κανών).[114]

As already mentioned, Rhabdas plagiarized the beginning of the *Arithmetics* in each of his *Letters*.[115] Metochites' allusions to Diophantos in Book II of his *Abridged Astronomical Elements* are drawn from Theon's *Commentary on the Almagest*.[116] In an autograph scholium to Ptolemy, *Geography* I.24, in Vat. gr. 176, fols. 19v–20r, Argyros solved, ἐκ τῶν Διοφαντείων "with Diophantine methods," the problem of finding a number that, added to a given number, has an assigned ratio to itself. This scholium was transcribed by Chortasmenos within his synoptic commentary on Ptolemy's *Geography* in Vat. Urb. gr. 80, fol. 39r–v.[117] As noted above, Chortasmenos also annotated Matrit. 4678 of Diophantos: he filled the margins left free by the previous scholiasts with annotations and added hundreds of infralinear remarks, as far as the beginning of Book III.

Mentions of Diophantos or of notions defined in the *Arithmetics* can also be found, in among others: Stephanos of Alexandria listing the authorities in a series of scientific domains;[118] John Chrysostomites (*c.* 1100) in his "dual" *Life* of John of Damascus and of Kosmas the Hymnographer;[119] a letter of Theophylactos of Ochrid, dated 1094, to the *protoasekretis* Gregory Kamateros, in which he lists the several scientific skills of the otherwise unknown *praktor* Theodore Chryselios;[120] a letter of Manuel Karantenos (*c.* 1200) to Constantinos Kaloethes, then *oikoumenikos didaskalos* in the Patriarchal School, boasting about his own many skills, acquired thanks to the teaching of Kaloethes

114 Valuable information on Diophantos come from four scholia, penned at the beginning of the 14th century but probably of ancient origin, to Iamblichos' writing on Nikomachos' *Introduction* in the earliest witness Laur. Plut. 86.3; they are edited in Diophantos, *Opera omnia*, ed. Tannery, vol. 2, p. 72, drawing from Iamblichos, *On Nikomachos' Introduction*, ed. Pistelli, pp. 127.11–13, 131.26–27, 131.29–30, 132.10–13 (on the latter scholium see Waterhouse, "Harmonic").

115 Tannery, "Notice," pp. 86.6–15 and 118.3–10, to be compared with Diophantos, *Opera omnia*, ed. Tannery, vol. 1, pp. 2.3–17 and 2.3–13, respectively. Rhabdas also mentions Diophantus: Tannery, "Notice," p. 118.15.

116 Compare Metochites, *Abridged Astronomical Elements*, ed. Derycke, pp. 51.9–15 and 52.15–53.4, with Theon, *Commentary*, ed. Rome, pp. 453.4–6 and 453.11–14. In the first passage, Metochites adds the name of Nikomachos and calls Diophantos' treatise Ἀριθμητικὴ σύνταξις.

117 Edition Tsiotras, Ἐξηγητική παράδοση, pp. 427–28.

118 Pseudo-Elias on Porphyry's *Isagoge*, πρᾶξις ιθ, § 30, in *Pseudo-Elias* (*Pseudo-David*), *Lectures on Porphyry's Isagoge*, ed. L.G. Westerink, Amsterdam 1967, pp. 38–39.

119 See Diophantos, *Opera omnia*, ed. Tannery, vol. 2, p. 36.6–19.

120 Theophylactos of Ochrid, *Letters*, ed. Gautier, vol. 2, p. 575.55–57.

himself;[121] Blemmydes describing his own education in his *Autobiography*;[122] Argyros describing the rule of multiplication of signs in his treatise on the extraction of an approximate square root.[123] In a letter to an unknown addressee,[124] accompanying τῆς Διοφάντου λογιστικῆς ὅσα τῶν θεωρημάτων οἷός τ' ἐγενόμην εὑρεῖν "all results of Diophantos' *Logistics* [he] had been able to find," Demetrios Kydones claims that they δόντος τινὸς βιβλίον, ᾧ λαθόντα καὶ ταῦτα ἐνέκειτο "laid unnoticed, in a book provided [to him] by someone." Kydones had managed to complete these results with proofs in the style of the arithmetical theorems of Euclid (namely, *Elements* VII–IX), ὁ γὰρ Διόφαντος ζητήματα μόνον προτείνας "for Diophantos had just proposed objects of research." This is not a description of the *Arithmetics*, assuming that Kydones did not have access to an otherwise unknown epitome. Nor can Diophantos' treatise, whose extant six books comprise 189 problems, remain unnoticed. The description fits perfectly, instead, short problems in *Rechenbuch*-style that Kydones must have found ascribed to the father of arithmetical zetetic.[125]

Phantom ascriptions to Diophantos were in fact not unheard of. The *Prolegomena to the Almagest* are attributed to him in Marc. gr. 303, fol. 31r (middle 14th century). The name of some Diophanes author of a geometric metrological compilation was enriched, in Ephrem's Seragl. G.İ.1, fol. 17v, with a *tau* in order to make it converge on the name of his renowned quasi-homonym. Psellos' epistle described above is entitled ἀπὸ τῆς Διοφάντου ἀριθμητικῆς in Scorial. Y.III.12 (gr. 282), fol. 73r (early 14th century). A fake extract from the *Arithmetics* (title ἐκ τῆς ἀριθμητικῆς Διοφάντου) can be read in Par. suppl. gr. 387, fol. 181r:[126] it is a short description of a method to calculate an approximate square root κατὰ τὴν τάξιν τῆς Ἰνδικῆς μεθόδου "according to the arrangement of the Indian procedure."[127] Planudes' *Great calculation* is followed in some manuscripts, among which Par. gr. 2381, fol. 12v (15th century), by a text that in Rossianus 986, fol. 236r (middle 15th century), becomes a further fake extract from the *Arithmetics* (title ἐκ τῶν τοῦ Διοφάντου ἀριθμητικῶν).

I now come to more substantial elaborations. Almost every Byzantine scholar versed in mathematical matters tackled the thorny issue of compounded

121 Criscuolo, "Due epistole," pp. 113.91–114.98.

122 Blemmydes, *Autobiography*, ed. Munitiz I.8.1–7.

123 Allard, "Petit traité," p. 18.1–4.

124 Kydones, *Letter* 347, ed. Loenertz, vol. 2, p. 287.3–17.

125 The result of Kydones' and of his addressee's (Argyros?) efforts might well be the five arithmetical problems ascribed to them, see below, p. 136.

126 Editions Diophantos, *Opera omnia*, ed. Tannery, vol. 2, p. 3.3–14; Hero, *Opera omnia*, ed. Heiberg, vol. 4, p. XV; Planudes, *Great calculation*, ed. Allard, p. 201.

127 A similar text can be read among the scholia to the *Elements*: it is *sch.* IX.11, in Euclid, *Opera omnia*, vol. 5, ed. Heiberg, p. 401.12–27.

ratios and of the removal of a ratio from a ratio; in our language, these are "simply" multiplying and dividing fractions. As usual, the trigger lay in ancient Greece.[128] The most celebrated result of Greek spherical trigonometry is the Sector Theorem. This is a powerful mathematical tool, suited to determine arcs of a great circle on the surface of a sphere. It is the keystone of some of the most important technical results of the *Almagest*; it is proved in *Almagest* I.13 and, in greater detail, in Theon's commentary thereon.[129] The Sector Theorem proves that, in suitable geometrical configurations, a ratio is compounded of two other ratios, thus: $a{:}b = (c{:}d)\circ(e{:}f)$; this relation has six terms $a \dots f$. In any application of the Sector Theorem in the *Almagest*, a relation of this kind is simply stated to hold, five of the six terms are numerically given, and one must find the sixth, which may hold any place in the sequence $a \dots f$. The procedure amounts to suitably performing the operation of ἀφαίρεσις "removal" of a ratio from a ratio. Since Ptolemy never explains how to do that, the gap was filled by Pappus and Theon in their commentaries on the *Almagest*, and by all subsequent generations of scholiasts thereon. Filling the gap entailed either producing general expositions that tried to unify the several cases of the operation of removal under a unitary treatment, or working out the calculations involved in a specific application of the Sector Theorem. The major role played by the Sector Theorem in the *Almagest* explains even the mere existence of most of these expositions. Byzantine contributions include: Leo the Mathematician in a long scholium that plunders a late antiquity scholium to the *Elements*;[130] Pachymeres' *Quadrivium*, Section IV, §§ 3–4;[131] Bryennios in a series of autograph scholia to the *Almagest* in his own exemplar, Par. gr. 2390 (2nd half of 13th century);[132] Planudes in a scholium to the *Elements*;[133] Barlaam, *Logistic*, Book V;[134] an anonymous set of six rules drawn from Barlaam and Theon of

128 See Acerbi, "Composition," for details and translations of all relevant texts.

129 Theon, *Commentary*, ed. Rome, pp. 535.10–570.12.

130 Leo's scholium, transcribed by the hand of the main copyist, at the end of *Elements*, Book VI, and together with other exegetic material, is at fols. 120r–121v of Bodl. Dorv. 301; it is edited at Euclid, *Opera omnia*, vol. 5, ed. Heiberg, pp. 714.17–718.22. The plundered scholium is at fols. 118v–119v of the same manuscript, and is edited *ibidem*, pp. 711.6–714.16. For an assessment of Leo's mathematical output, see Acerbi, "Types," pp. 125–27 and 164–66, with a complement in Id., "Composition," pp. 156–59.

131 Chapters 8–10 of Book II of Metochites' *Abridged Astronomical Elements* deal with compounded ratios and removal of a ratio from a ratio; we read them in Vat. gr. 181, fols. 26r–35r. This is nothing but a plagiarism, with enormous amplifications (Metochites' fondness of περιβολή is legendary), of what we read in Pachymeres' *Quadrivium*.

132 See Acerbi/Pérez Martín, "Scolii."

133 It is *sch*. VI.6 in Euclid, *Opera omnia*, vol. 5, ed. Heiberg, pp. 327.12–329.17.

134 Chortasmenos wrote a tract on compounded ratios and removal of a ratio from a ratio (we read it in the autograph Vindob. suppl. gr. 75, fols. 234r–256v, a copy of which is

Alexandria;[135] a short rule in Par. gr. 2450, fol. 207v; Kydones in an autograph scholium to the *Almagest* in his own exemplar, Laur. Plut. 28.1;[136] an unknown but certainly Byzantine author who transformed a scholium to the *Almagest* from late antiquity into a richer text, which the accidents of transmission made ascribed to the 5th-century Neoplatonic philosopher Domninos;[137] a very short text of Plethon (!);[138] a section of the computational primer to the *Almagest* written by George of Trebizond.[139]

Five short arithmetical texts are ascribed to Kydones and to Argyros.[140] Three of them expound procedures, with different degrees of generality, for the sum of an arithmetic progression; a fourth provides a proof of one such procedure. Other writings in which this issue is treated are Moschopoulos' treatise on magic squares (see just below) and a couple of *Rechenbücher*: *Anonymus* P, nos. 23, 37, 110–13;[141] *Anonymus* 1436, nos. 57–60.

A treatise on magic squares, entitled Παράδοσις εἰς τὴν εὕρεσιν τῶν τετραγώνων ἀριθμῶν *Account for the discovery of the square numbers*, was written by Moschopoulos; it was composed on Rhabdas' spur, of whom Moschopoulos was an earlier contemporary.[142] A magic square is the arrangement, on the $n^2$ cells of a "chessboard," of the first $n^2$ integers so that the sum of the numbers in any row, column and in the two main diagonals is the same. It is obvious that such a sum (the "side" of the magic square) is equal to the sum of the $n^2$ arranged integers, divided by the number of rows (or columns), namely, by $n$. Moschopoulos' treatise begins with some standard Euclidean definitions and with that of the "side" of a magic square; a prescription follows giving a rule for the sum of any initial segment of the sequence of natural numbers (this is useful, as just

Ambros. C 263 inf., fols. 195r–212r [16th century]). This is nothing but a verbatim plagiarism of a part of Book V of Barlaam's treatise, in particular propositions 18–23. Diophantine-style elaborations by Chortasmenos, together with other material on determining the "numerical value" of a ratio, are also found at fols. 277r–281v of the Vienna Manuscript.

135 They are at least contained in Ambros. E 76 sup., fols. 110r–111r, and in its apographs Ambros. P 72 sup., fol. 59r–60r, and R 117 sup., fols. 153r–v.

136 Edition in Acerbi, *Logistic Texts*.

137 See Acerbi/ Riedlberger, "Scolio tardo-antico."

138 This is Text 3 in Acerbi/Martinelli Tempesta/Vitrac, "Interventi autografi."

139 Edition in Acerbi, *Logistic Texts*.

140 Two problems ascribed to Kydones, three to Argyros; edition Acerbi, "Problemi."

141 For no. 110, see also, at fol. 208v of the same manuscript as *Anonymus* P, the text edited in Hero, *Opera omnia*, vol. 5, ed. Heiberg, pp. xvi.16–xvii.5 (a comparison of the two versions in Acerbi, "Problemi," Text 22); for nos. 111–12, see also Vindob. phil. gr. 225 (1st half of 15th century), fol. 154v (cf. *ibidem*, vol. 5, p. cvii).

142 Edition Tannery, "Traité," analysis in Sesiano, "Carrés magiques"; see also Tannery, "Manuel Moschopoulos et Nicolas Rhabdas." Moschopoulos was a pupil of Planudes.

seen). A list of methods is then described for arranging, in an assigned chessboard, the first $n^2$ integers in such a way that the final disposition is a magic square. J. Sesiano, who analyzed the treatise and its likely sources (the argument was thoroughly investigated by Arabic mathematicians), is categorical: "Il apparaît de l'analyse de son traité que Moschopoulos s'est trouvé devant quelque écrit sur les carrés magiques dont il ne comprenait pas le texte, s'il y en avait un, mais dont il a cherché à analyser les figures."[143]

Barlaam composed a Λογιστική *Logistic* in six books, which is in fact a fully-fledged treatise of arithmetic formulated in impeccable demonstrative style; it must be considered the most accomplished product of Byzantine mathematics, with no parallel in ancient Greece.[144] Barlaam's goal is expressly stated in the preface: to provide logistic techniques useful in astronomy with a demonstrative basis. He also briefly describes the contents of his treatise, according to the following outline. Book I (27 propositions): addition and subtraction of parts (these are our fractions). Book II (39): multiplication and division of degrees and parts (in prop. II.39, the Heronian approximation of a square root is discussed; the proof shows that any iteration gives a better approximation). Book III (12): multiplication and division of degrees and minutes (that is, this book deals with the sexagesimal system). Book IV (12): multiplication of straight lines by straight lines and division of regions by straight lines (these are lengths with respect to a fixed unit of measurement; emphasis is put on issues of homogeneity). Book V (23): compounded ratios and removal of a ratio from a ratio. Book VI (21): how, from given magnitudes, what is sought becomes given.[145] Each book is opened by a set of specific definitions; the propositions alternate theorems and problems; the latter usually have a counterpart in a specific elementary operation.

Barlaam also wrote a short monograph, entitled Ἀριθμητικὴ ἀπόδειξις ἐπ' ἀριθμῶν ἀνάλογον ἔχουσα τοῖς γραμμικῶς ἐπὶ εὐθειῶν ἐν τῷ δευτέρῳ τῶν στοιχείων ἀποδεδειγμένοις *Arithmetical proof for numbers keeping analogous to what has been rigorously proved for straight lines in the second of the Elements*, in which he rewrote propositions 1–10 of Book II of the *Elements* in arithmetical language.[146] He prefaces it with a set of definitions; Barlaam's proofs hinge on ar-

143 Sesiano, "Carrés magiques," p. 392.
144 Edition Barlaam, *Logistic*.
145 The magnitudes are numerical proportions and regions, rectangles and right-angled triangles; here "given" means "assigned in numbers."
146 Edition Euclid, *Opera omnia*, vol. 5, ed. Heiberg, pp. 725–38, but just reprinting Dasypodius' of 1564, and without the proem, for which see Vitelli, "Indice," pp. 543–44 (Carelos, "Prooimion," did not know of Vitelli's earlier edition). Recall that, in the arithmetical section of his *Quadrivium* (§§ 47–54), Pachymeres proposed number-theoretical versions

ithmetical theorems proved in the *Elements* and on other, elementary, arithmetical results. The most remarkable fact about such a rewriting is that the propositions, whose original, geometrical proofs are independent of each other, are organized in a connected deductive sequence, very much as in the (strictly geometrical) Heronian rewriting of the same Book II.[147] Propositions 1–3 are so basic that they cannot be linked in this way; from prop. 4 on, the preceding proposition(s) within the sequence that figure in each proof are as follows: 4 (2); 5 (4), 6 (4); 7 (4, 3); 8 (4, 7); 9 (5, 4); 10 (7, 6). From prop. 7 on, no arithmetical results other than those just indicated are used. Prop. 7 is also the only one which is grounded on the same previous propositions both in Hero and in Barlaam.

Arithmology is a body of structured arithmetical lore with metaphysical and mystical overtones. A well-represented sub-genre is that of *Theology of Arithmetic*: a list of properties and attributes of the numbers within the Decad (unit included, which is not a number). As seen above, from Greek antiquity we still read, among others, Anatolios' treatise and the pseudo-Iamblichean *Theology of Arithmetic*. Photios, *Bibliotheca*, codex 187, describes Nikomachos' *Theology of Arithmetic* (now lost)—and declares that it is a heap of nonsense. If Greek arithmology has been studied to a reasonable extent, Byzantine has not; I shall only offer a glimpse into the subject. In the letter mentioned above, Psellos also alludes to the arithmological elaborations contained in the so-called "letter of Petosiris to Nechepson" and in the "little Pythagorean plinth," just to affirm that they are nonsense.[148] The same Psellos excerpted, from Books V–VII (now lost) of Iamblichos' *Collection of Pythagorean Doctrines*, two short texts of arithmological contents, Περὶ τοῦ φυσικοῦ ἀριθμοῦ *On physical number* and Περὶ τῆς ἠθικῆς ἀριθμητικῆς καὶ τῆς θεολογικῆς *On ethic and theologic arithmetic*.[149] Similar arguments are treated in Περὶ τῶν ἰδιωμάτων τῶν ἀριθμῶν *On the properties of numbers*.[150] Pediasimos also practiced the

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of propositions 3–10 of Book II of the *Elements*. The proofs are all replaced by numerical exemplifications.

147 For which see Hero, *Metrica*, ed. Acerbi/Vitrac, pp. 36 and 368–71. The Heronian rewriting is only attested in Arabic.

148 For indications on the former of the two Neo-Pythagorean texts see Riess, "Nechepsonis," items 41–42; for an edition of the latter see Tannery, "Fragments." An analysis of the mathematics behind such kind of writings is in Neugebauer/Saliba, "Numerology." On the stemmatic structure of the entire tradition of Greek arithmological writings, see Robbins, "Tradition."

149 Edition Tannery, "Psellos sur les nombres" (who in fact had access to a debased version, conflating and curtailing the two texts); O'Meara, "New Fragments."

150 Edition S. Weinstock, *Catalogus Codicum Astrologorum Graecorum. IX.1. Codices Britannicos*, Bruxelles 1951, pp. 103–6. The just-mentioned texts are Moore, *Iter Psellianum*,

arithmological genre: we can read short writings by him Περὶ τοῦ πῶς ἑπτάμηνος ἢ ἐννεάμηνος ὁ τόκος σώζεται *On why a seven months' or a nine months' child survive* (geometrical variations are also found in the manuscripts) and Περὶ τῶν θ μουσῶν *On the nine muses*. More generally, the commentaries on Hesiod's poems triggered plenty of arithmological annotations, by Pediasimos himself and by his contemporaries John Galenos (2nd half of 13th century; *PLP* 3521) and John Protospatharios (early 14th century; *PLP* 8731), as well as in the collections of John Tzetzes (born *c.* 1110) and Moschopoulos.[151] Gregoras wrote a short monograph on the properties of "venerable" number seven.[152]

## 5 Harmonic Theory

Harmonic theory studies consonant intervals and their organization in higher-lever structures. The tradition dating back to Pythagorean elaborations and culminating in Ptolemy's *Harmonics* employs arithmetical methods; an alternative, empirical tradition takes as reference text Aristoxenos' *Harmonics*. I start again by describing some second-order activities on Greek musical treatises.

A Byzantine recension of Euclid's *Sectio canonis*, ascribed to a certain Zosimos, is attested in Marc. gr. VI.3, fols. 9r–17r. This text was later heavily corrected, in the same manuscript, by at least three, if not five hands. Zosimos' recension, supplemented by all layers of corrections, was very productive thanks to the abundant progeny of its direct apograph Marc. gr. 322, penned for Bessarion by John Rhosos and that the Cardinal regarded as one of his best codices (annotation at fol. 1r).

A recension of Ptolemy's *Harmonics* (Düring's class f) gives rise to a rich branch of the tradition, entirely stemming from Monac. gr. 361a (end 13th century). We also know of an edition by Gregoras about 1335.[153] Gregoras had

PHI.154, 155, 160.

151 Edition of the former text in Cumont, "Opuscule," pp. 14–18, and in V. De Falco, *In Ioannis Pediasimi libellum de partu septemmestri ac novemmestri nondum editum*, Neapoli 1923, pp. 4–9 (geometrical versions at pp. 20–21 and 27–28, respectively), of the latter *ibidem*, pp. 14–16. For the commentaries on Hesiod, see De Falco, "Aritmologia," who also presents supplementary material.

152 Edition Sbordone, "Ebdomadario." Gregoras' writing can also be read, partly autograph, in Vat. gr. 704, fols. 4r–6r: Bianconi, "Libri d'autore."

153 This is the likely date of a letter to Michael Kaloeidas (Gregoras, *Letter* 114, ed. Leone, vol. 2, pp. 301.95–302.107) in which Gregoras speaks about his having revised Ptolemy's treatise: see the discussion at Ptolemy, *Harmonics*, ed. Düring, pp. lxxviii–lxxxviii. In the same letter, Gregoras describes his works on Easter Computus and on the astrolabe (for

access to manuscripts of class f and of a class apparently unaffected by any recension; he also supplied part of chapter III.14 and the entire chapter III.15 (also contained in Monac. gr. 361a), as is borne out by some scholia preserved in a number of manuscripts. This is Düring's class g; the common source of this rich branch of the tradition is Par. Coislin 173, fols. 31v–111v (1st half of 14th century), annotated by Gregoras himself. A further recension of the *Harmonics* was written by Argyros, whose fair copy is preserved (but note that Argyros was used to correct *in scribendo*) in the autograph Vat. gr. 176, fols. 100r–159v.[154]

As for less mathematically oriented authors, the tradition of Aristides Quintilianus' *On Music* admits of two branches (called ν and δ) which carry different Byzantine recensions. The manuscripts on which the entire tradition of Aristoxenos' *Elements of Harmony* depends were extensively corrected by Byzantine hands.[155]

Several manuscripts of purely musical contents were produced, and actively annotated and corrected, during the Byzantine period.[156] The latest of them also included Bryennios' Ἁρμονικά *Harmonics*. Planudes, in his *Letter* 68 (written before 1294) addressed to Theodora Raoulaina (d. 12/06/1300; *PLP* 10943), complains about the loss of a codex of his own containing musical writings, since this would have allowed him to correct in the best possible way a manuscript of the same contents that she owned.[157]

I will now briefly describe the main Byzantine texts in harmonic theory. In *Anonymus* 1007, the musical section is quite short and treats tones and intervals and their properties, systems, genera, *tonoi*, modulations and composition; sources include Aristoxenic lore, Theon of Smyrna, Cleonides, Nikomachos'

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the latter, see also *Letter* 148, to Nicholas Cabasilas). Gregoras' recension of the *Harmonics* was repeatedly requested to the author by some Nicholas Pepagomenos: see Gregoras, *Letter* 20, ed. Leone, vol. 2, p. 422.38–43.

154 See Ptolemy, *Harmonics*, ed. Düring, pp. xxxiii and lxxxviii–lxxxix. Argyros also reconstructed the part of chapter II.14 lost in the rest of the tradition, as is borne out by a scholium of his at Vat. gr. 176, fol. 138v (see Mountford, "Harmonics").

155 See the *prolegomena critica* in Aristides Quintilianus, *On Music*, and Aristoxenos, *Elements of Harmony*.

156 Detailed descriptions of musical manuscripts are in Mathiesen, *Ancient*; for the most important of them see also Mathiesen, *Apollo's Lyre*, pp. 651–55, with a useful table. However, the dates of some of these manuscripts must be corrected (Acerbi/Pérez Martín, "Scolii," p. 105 and n. 13), in particular those of Marc. gr. VI.3 (in fact 11th century) and of the musical portion of Vat. gr. 2338 (imitative writing of 2nd half of 13th century: see also Acerbi/Gioffreda, "Harmonica"; recall that Vat. gr. 191 and 192 also contain extended musical sections). The other musical collection earlier than 13th century is Marc. gr. VI.10, of late 12th century. The first two manuscripts mentioned are among the earliest witnesses of both Euclid's and Aristoxenus' treatises.

157 Planudes, *Letter* 68, ed. Leone, p. 103.10–16.

*Encheiridion*, Bacchius, Gaudentius; a comparison with geometry is drawn to justify the absence of irrational quantities among numbers.[158] Short writings on harmonic theory also feature in Psellos' wide-ranging production. These include three letters on musical matters;[159] the Προλαμβανόμενα εἰς τὴν ῥυθμικὴν ἐπιστήμην *Preliminaries to Rhythmic Science*;[160] a section of a tract Περὶ τραγῳδίας *On tragedy*;[161] a more substantial text on the soul's psychogeny in Plato's *Timaeus*;[162] three shorter exegetical tracts on the *Timaeus* again.[163] The last two types are made of extracts from Proclus' commentary. Note that, as for many writings ascribed to him, Psellos' authorship is often uncertain. A writing of Ἐπιστασίαι μερικαί *Specific Remarks* on music by Pediasimos mainly deals with musical intervals; its editor even wonders which reason might "motiver … la publication d'un traité où l'on trouve des idées aussi fausses et des fautes aussi grossières."[164] In Pachymeres' *Quadrivium*, the musical section treats intervals (also related to the motions of the planets), systems, genera and shades, consonant and dissonant intervals, *tonoi* and their relations with Byzantine *echoi*; sources include Aristoxenos, Cleonides, Nikomachos' *Introduction* and *Encheiridion*, Ptolemy's *Harmonics*, Bacchius, Gaudentius, Aristides Quintilianus.[165] Both Pachymeres' and *Anonymus* 1007 offer only more or less intelligent synopses of Greek harmonic theory.

The most accomplished product of Byzantine harmonic theory is Briennios' *Harmonics* in three books.[166] He relied on the series of sources listed above—with special focus on Aristides Quintilianus—and on Pachymeres' exposition.

158 Edition *Anonymus* 1007, pp. 65.8–72.16; analysis in Richter, "Überlieferungen," pp. 94–98, and Richter, "Psello's Treatise." The best account of Byzantine harmonic theory is by far the one in Richter, "Überlieferungen."

159 Edition Ch.-É. Ruelle, *Études sur l'ancienne musique grecque*, Paris 1875, pp. 120–27. See also Moore, *Iter Psellianum*, PHI.163 (Psellos' tract includes a proof that there cannot be more than five regular solids, and the definitions prefacing Book X of the *Elements*), PHI.162; the first letter edited by Ruelle is not included in Moore's catalogue.

160 Edition R. Westphal, *Die Fragmente und die Lehrsätze der griechischen Rhythmiker*, Leipzig 1861, pp. 74–77. This is Moore, *Iter Psellianum*, GRA./RHE.12.

161 Edition Browning, "Byzantine Treatise," in particular section 5. This is Moore, *Iter Psellianum*, GRA./RHE.14.

162 Edition Vincent, *Notice*, pp. 316–37. This is Moore, *Iter Psellianum*, PHI.72. The same text also circulated ascribed to Soterichos (edition in Soterichos, *Scholia*).

163 Edition D.J. O'Meara, *Michaelis Pselli philosophica minora*, vol. 2, Lipsiae 1989, nos. 4–6. These are Moore, *Iter Psellianum*, PHI.73–75.

164 Edition and analysis in Vincent, *Notice*, pp. 290–315. The quote is from p. 289.

165 Edition in Pachymeres, *Quadrivium*, pp. 97–199; analysis in Richter, "Überlieferungen," pp. 98–101.

166 Edition Bryennios, *Harmonics*. Detailed description, with indication of the sources, in Richter, "Überlieferungen," pp. 101–03; Mathiesen, "Aristides Quintilianus," and *Apollo's Lyre*, pp. 657–67.

Bryennios reworked, expanded, clarified, and harmonized his sources so as to give rise to a markedly authorial product. Book I is in line with the Aristoxenian tradition and deals with notes, intervals, systems, genera and shades, modulations; Book II mainly rests on Ptolemy's *Harmonics* and treats consonant and dissonant intervals, the *tonoi*, and the division of the harmonic canon; Book III combines the two traditions and deals with *tonoi*, *echoi* and melodies; this book also shows remarkable coincidences with *Anonymus Bellermann* (see below).

Metochites' ideas on harmonic theory are expounded in his long *Poem* 10 Περὶ τοῦ μαθηματικοῦ εἴδους τῆς φιλοσοφίας καὶ μάλιστα περὶ τοῦ ἁρμονικοῦ *On the mathematical branch of philosophy, and on harmonics in particular*; this is based mainly on Bryennios' *Harmonics*, and possibly also on the musical section of Pachymeres' *Quadrivium*.[167] Gregoras restored part of chapter III.14 and the entire chapter III.15 of Ptolemy's *Harmonics*; he also wrote a commentary on Synesios, *De insomniis*, featuring several passages in harmonic theory.[168] A scholium on musical intervals is ascribed to Gregoras in manuscripts copied by Prodromenos.[169] Barlaam wrote a refutation of the chapters added by Gregoras to Ptolemy's *Harmonics* III and of chapter III.16, of ancient origin but which is out of place in the manuscripts.[170] This pamphlet is more a piece of textual criticism than of harmonic theory: Barlaam states six conditions that should be fulfilled if the chapters were to be congruous with their original titles and with the contents of the *Harmonics*,[171] and shows that none of them is met with in the restored chapters. The tract includes a geometrical argument about the straight line being the shortest path between two points.

It remains only to mention two collections of excerpts. The first is the early collection of three musical summaries known as *Anonymus Bellerman*, on which Bryennios relied in part: the first text deals with rhythmic signs and melodic structures; the second with music, its subdisciplines and the genera in

167 See Bryennios, *Harmonics*, ed. Jonker, p. 18. Edition in Metochites, *Poems*, ed. Polemis, pp. 176–212, translation in Polemis, *Metochite*, pp. 202–34.

168 Edition of the former in Ptolemy, *Harmonics*, ed. Düring, pp. 109.8–111.12 (contrary to what their titles would entail, these chapters only deal with the relations between the notes in the Perfect System and the aspects of the planets), of the latter P. Pietrosanti, *Nicephori Gregorae Explicatio in librum Synesii "De insomniis." Scholia cum glossis*, Barii 1999. An extract of musical interest from the commentary is edited and translated in Vincent, *Notice*, pp. 281–89.

169 See Guilland, *Essai*, p. 275, for a short description, and Acerbi, "Problemi," Text 6 and n. 21 on pp. 137–38, for an edition and a detailed description.

170 Edition Ptolemy, *Harmonics*, ed. Düring, pp. 112–21 (mere reprint of J. Franz, *De musicis graecis commentatio*, Berolini 1840, pp. 14–23). Barlaam never mentions Gregoras.

171 The titles are independently preserved in the *pinakes* of the treatise.

each of these, passing then to the seven Aristoxenian categories of harmony; the third expounds generalities on music, again the seven Aristoxenian categories, and closes with disparate material.[172] The second collection is a debased farrago of notions, known as *excerpta neapolitana*, published on the basis of Napoli, Biblioteca Nazionale, III.C.2, fols. 41v–45r (end 15th century).[173]

## 6 Geometry

Geometry deals with the properties of the abstract plane and solid objects bounded by lines and surfaces. Such properties are established by proofs formulated in a demonstrative style; they are regularly illustrated by line diagrams. The aim of geometric metrology and geodesy, instead, is to measure the same objects assuming a set of reference measures (linear, plane, or solid); it is invariably formulated in a procedural or algorithmic style. Such prescriptions, with the exception of those of "fiscal geometry," are implicitly validated by suitable geometrical arguments.[174] These two disciplines will be treated in the following section.

Byzantine geometrical discourse is fragmented and almost exclusively consists of second-order activities on ancient Greek treatises: transcriptions (and their contamination), recensions, conception and collection of scholia, especially for isagogic purposes. As for the authors of interest, Euclid was of course the most important one;[175] Apollonios and Serenos surface together in the 12th century (Vat. gr. 206, carrying no scholia) and were studied to some extent; Archimedes and Pappos were transliterated during the 10th century but afterward they went totally unnoticed;[176] the *codex unicus* of Hero's *Metrics*,

172 Editions and detailed discussion in Najock, *Anonymus Bellermann* and *Drei anonyme*.

173 Edition Jan, *Musici*, pp. 411–20. See Acerbi/Panteri, "Eratosthenes," for their earliest witness.

174 Such a validation is programmatically pursued only in Hero's *Metrics*.

175 There are ninety-six witnesses of the *Elements* earlier than 1700.

176 The commentaries by the early 6th-century Neoplatonic philosopher Eutocios on Archimedes' *On the sphere and the cylinder* I–II and *Measurement of a circle* were edited within the school of the architect Isidoros of Miletos (Archimedes, *Opera omnia*, vol. 3, ed. Heiberg, pp. 48.28–31, 224.7–10, 260.10–12), the addressee of Eutocius' Apollonian commentary. The same scholarly circle probably revised the two Archimedean treatises commented on by Eutocios and was surely responsible of adding the so-called "Books XIV–XV" to the *Elements*; "Book XIV" was in fact composed by Hypsicles in the 2th century BC; "Book XV" itself, instead, originates in Isidoros' school (cf. Euclid, *Opera omnia*, vol. 5, ed. Heiberg, p. 50.21–2); both writings were intended to complete the theory of regular polyhedra expounded in *Elements*, Book XIII. Archimedes was recovered in Western Europe, *c.* 1269, by the renowned translator William of Moerbeke, then during Italian

Seragl. G.İ.1, has never left Constantinople but it was only exploited in the mid-15th century, by Comtino.[177]

Greek scientific writings have very often undergone revisions in the Byzantine period and sometimes quite heavily; one may well say that any such writing presents at least one line of transmission consisting of a Byzantine recension. Recensions of technical texts are frequently met with for an obvious reason: such writings were used, appropriated, and taught by technically skilled authors. Even in the case of strictly mathematical works that have benefited from a final redaction and have not been disfigured by early scribal mistakes, Greek mathematical style is so conceived as typically to produce texts that are not "saturated" from the lexical, syntactical, or deductive point of view. Still, they can be "saturated" fairly easily and almost univocally. Of course, there was no instruction manual as to how to write a mathematical text: this is the result of a shared practice and of the author becoming deeply acquainted with the way Greek mathematical works are written. In the perception of the Byzantine scholars who authored the revisions, such a shared stylistic practice was continuous from Euclid to their own time. In a sense, what was perceived as canonical in a Greek mathematical text was its style, not the text itself: hardly anyone would dare to extensively correct Plato or Pindarus, while any scholar could feel entitled to thoroughly revise at least in points of style even such a mathematical genius as Apollonios.[178]

The situation with the *Elements* is unclear since Heiberg almost completely neglected later manuscripts in his edition, and a systematic collation of them has been undertaken only recently:[179] one does not find, in the tradition of the *Elements*, Byzantine recensions *stricto sensu*, but a great number of independent and very localized modifications, maybe simply introduced by

Renaissance (an exhaustive account, with edition of all relevant texts, in Clagett, *Archimedes*). The ancestor of the entire tradition of Pappus' *Collection* is Vat. gr. 218 (10th century); it only carries *scholia vetera*; it passed to the West earlier than the mid-13th century, but later than *Anonymi Miscellanea Philosophica* 10, ed. Pontikos 1992, pp. 27.1–29.4 (this compilation was composed in the circles of Michael Psellos) and than John Tzetzes, d. 1180–85, who obviously draws on the Anthemios fragment in this manuscript (see below) in his *Chiliades*, II.121–30 and 152–59, XI.586–618; its apographs are not earlier than the second decade of the 16th century (see Treweek, "Pappus"). On the early passage of these and other scientific manuscripts to the West, see now Acerbi/Vuillemin-Diem, *Moerbeke*, ch. 8.

177 See Hero, *Metrica*, ed. Acerbi/Vitrac, pp. 549–56.

178 I have dealt at length with this phenomenon in Acerbi, "Byzantine Recensions," some of whose results I summarize here.

179 By B. Vitrac, who is preparing the new critical edition of Euclid's treatise for the Collection des Universités de France. I use some of his results that Vitrac has kindly communicated to me.

well-informed copyists. This phenomenon can be already detected in the late 11th and early 12th centuries (Vindob. phil. gr. 31, Par. gr. 2344 and 2466) and goes as far as Chortasmenus' own exemplar, Mutin. α.T.8.21, filled with hundreds of scholia in his hand. As for Malachias' Par. gr. 2342, he made eclectic choices from readings that are peculiar to a number of manuscripts. In this case, then, the modified text cannot be regarded as the result of a recension, but of systematic and deliberate contamination. A codex, once owned by Bessarion, whose loss must be regarded as mostly regrettable is the one in which Argyros transcribed and annotated the *Elements*, and possibly other geometrical writings. A part of Argyros' scholia drawn from this exemplar was printed in Greek (only for some definitions of Book V) or in Latin translation (preliminary material, and books I–VI) by Konrad Rauchfuss (Cunradus Dasypodius) in 1573 and 1579, respectively.[180] The set of scholia translated by Rauchfuss appears to coincide almost exactly with the collection in Par. suppl. gr. 12, fols. 9r–34r (middle 16th century); the only other trace of scholia to the *Elements* ascribed to Argyros is the collection in Cambridge, University Library, Gg.II.33, fols. 153v–176r (1st half of 16th century). A very peculiar intervention in a mathematical manuscript was performed by Plethon; he replaced a bifolium of Marc. gr. 301 (1st quarter of 15th century) to transfer postulates 4 and 5 of the *Elements* among the "common notions," as suggested by the 1st century BC scholar and polymath Geminus.[181]

A Byzantine recension of Euclid's *Data* is attested in Ambros. A 101 sup. (1st half of 16th century) and Upsal. gr. 50 (17th century). This recension is similar to that attested in Marc. gr. 301.[182] Par. gr. 2342 also contains a recension, different from that in Ambros. A 101 sup.

We only read Apollonios' *Conics* in a series of recensions, a later one possibly modifying the text of an earlier one. As mentioned already, the entire tradition depends on Vat. gr. 206, that contains the edition, composed by collating a number of divergent witnesses and limited to Books I–IV, prepared by Eutocios. A thorough Byzantine recension is witnessed by Ambros. A 101 sup. and Malachias' Par. gr. 2342. A Byzantine recension of Serenos' treatises, with exactly the same characters as that of Apollonios' *Conics*, is contained again in

180 Labowsky, "Cardinal Bessarion's."

181 See Acerbi/Martinelli Tempesta/Vitrac, "Interventi autografi," pp. 417–26.

182 Whose variant readings are listed, as a rich series of corrections apposed by a 15th-century hand to Vat. gr. 204 (9th century), at Euclid, *Opera omnia*, vol. 6, ed. Menge, pp. xviii–xxi. The recensions contained in these manuscripts (see also below) are studied in Decorps-Foulquier, "Corpus"; Acerbi, "Byzantine Recensions," pp. 154–59.

Ambros. A 101 sup. and Par. gr. 2342.[183] As it should be expected, Par. gr. 2342 also contains a thorough recension of Eutocios' commentary on Apollonios' *Conics*.[184] As is usual with commentaries included in this manuscript and in its companion Vat. gr. 198, Eutocios' text is transcribed in the margins of Apollonios' treatise.

It is even difficult to estimate the number of scholia apposed in Byzantine times to Greek mathematical texts; they certainly exceed one hundred thousand items. Yet, just a few Byzantine scholars are indicated as authors of scholia to the *Elements*. These include Leo the Mathematician, as we have seen above; Psellos, to whom *sch.* I.40 and I.49 are ascribed in a number of manuscripts; Pediasimos, with two scholia in Laur. Plut. 28.2 (12th century the surviving original portion); Planudes, for *sch.* VI.6 and X.223 and three further annotations in Laur. Plut. 28.2;[185] *sch.* VI.58 is ascribed to some Δημητρίου ⟨Kydones?⟩ in Bologna, Biblioteca Comunale dell'Archiginnasio, A 18, fol. 131v;[186] however, the same scholium can be read, in the hand of the main copyist, in Bodl. Dorv. 301 (penned in 888), fol. 114r. A number of scholia in the Bologna manuscript are also ascribed to Theodore Cabasilas (14th century; *PLP* 10089); Heiberg claims that the hand of these annotations, and of so many others in the same manuscripts, is that of Cabasilas himself, who therefore refers to himself in the third person.[187] One must note that, as usual, Cabasilas largely (but not exclusively) resorted to a previous collection (the so-called *scholia vindobonensia*) to compose his corpus, drawing in particular from Laur. Plut. 28.2.

183 Serenos, *Opera omnia*, ed. Heiberg, pp. v–ix; Heiberg also included the variant readings of the Paris codex in the apparatus.

184 Apollonios, *Opera omnia*, ed. Heiberg, vol. 2, pp. vi–viii; the variant readings of the Paris manuscript are recorded in the critical apparatus.

185 The two series in Laur. Plut. 28.2 are edited in Heiberg, "Om Scholierne," pp. 272–75. These (and also *sch.* X.223: Pérez Martín, "Vindob.") are autograph annotations, their authors referring to themselves in the third person. This manuscript contains many more autograph annotations in the hands of Pediasimos and Planudes (see Pérez Martín, "Écriture"). The scholia to the *Elements* are identified by the number assigned to them in Euclid, *Opera omnia*, ed. Heiberg, vol. 5.

186 Fols. 1r–35v of this manuscript (10th century: Acerbi/Pérez Martín, "Thessalonique") contain a list of all the principles and enunciations of the *Elements* and the *Data* (about 600 items). An excerptum like this of the "mathematical contents" of a (series of) treatises has no parallels in other Greek mathematical manuscripts; it has never been studied, but it is likely to have a Byzantine origin.

187 Edition and commentary in Heiberg, "Om Scholierne," pp. 263–72, discussion in Acerbi/Pérez Martín, "Thessalonique"; to the annotations there edited for the first time, one must add all scholia of the same hand already published in Euclid, *Opera omnia*, ed. Heiberg, vol. 5, and there denoted $\beta^2 + b^2$, $\beta^3 + b^3$.

One must not forget the many scholia by Arethas in Bodl. Dorv. 301.[188] Finally, a number of annotations to works by Euclid and Ptolemy has very recently been ascribed to the renowned scholar Manuel Chrysoloras, who owned several of Greek scientific manuscripts.[189]

As for the isagogic compilations related to the *Elements*, these are collections of definitions and scholia thereon, intended to introduce the subject matter of the whole treatise or of single books. The first genre, which more or less coincides with the second in the case of Book I, was practiced from late antiquity, in the form of series of extracts from Proclus' commentary. Two such standard compilations precede or surround the very beginning of the treatise (and of course also Book I) in most of the earliest witnesses of the *Elements*: one, contained in Vat. gr. 190, fols. 3r–13v (early 9th century), certainly dates back to late antiquity, the other, whose earliest witness is Bonon. A 18, fols. 36r–45v, is of likely Byzantine origin.[190] Two other isagogic compilations concern Books V and X. The latter is first found in Par. gr. 2344, fols. 358r–366v, and was then transmitted to encyclopaedias like Vat. gr. 192 (see above); the former was certainly assembled by Prodromenos, who was very likely also responsible for ascribing the compilation introducing Book X to Psellos. Prodromenos also was the author of two other compilations of this kind, preserved in Par. gr. 1846, the second volume of a huge isagogic enterprise in his autograph and focussed on Aristotle's logical works. The first compilation contains a series of extracts from *Elements*, Books I–II, accompanied by scholia drawn from Par. gr. 2344 and entitled θεωρήματα τοῦ γεωμέτρου Εὐκλείδου, ὧν ὁ Ἀριστοτέλης σποράδην μέμνηται ἐν τῇ πραγματείᾳ τῆς λογικῆς αὐτοῦ ἀποδείξεως *Theorems of the geometer Euclid, which Aristotle mentions here and there in his treatise on logical proof*. The second compilation is a series of extracts from Nikomachos' and from Philoponos' commentary thereon, entitled τὰ τοῦ ἀριθμητικοῦ

188 His annotations, in majuscule script, can hardly be distinguished from those of the main copyist; both hands are denoted B in Euclid, *Opera omnia*, ed. Heiberg, vol. 5.

189 The mark of ownership is a short bilingual title (Greek and Latin) describing the contents of the manuscript. We find such titles in Par. gr. 2345 + Vat. gr. 1316, fols. 337–52 (Euclid's *Elements* + *Optics*, recension A, the former heavily annotated by Chrysoloras—note that the very end of the *Optics* has remained in Par. gr. 2345: it is the misplaced fol. 223), Vat. gr. 191 (Chrysoloras annotated Euclid's *Optics*, recension B, and Ptolemy's *Geographia*; the *Optics* scholia, which mainly amount to a collation with recension A, are edited in Euclid, *Opera omnia*, ed. Heiberg, vol. 7, the hand being denoted **v**[1]), Vat. gr. 2176, Ferrara, Biblioteca Comunale Ariostea II.178 (*Almagest*), Laur. Plut. 28.13 (astronomical treatises). On all of this, see Acerbi/Bianconi/Gioffreda, *Crisolora*.

190 See Acerbi, "Types," pp. 117–18. The pseudo-Heronian *Definitions*, especially with the late-antiquity additions, may also be included in this category; this compilation, however, was intended to serve as an introduction to the whole of geometry.

Νικομάχου θεωρήματα περὶ ἀριθμοῦ περιττοῦ καὶ ἀρτίου καὶ τετραγώνου καὶ κύβου, ὧν μέμνηται Ἀριστοτέλης σποράδην ἐν τῷ πρώτῳ τῆς ἀποδεικτικῆς *Theorems of the arithmetician Nikomachos, which Aristotle mentions here and there in the first ⟨book⟩ on proof.*[191]

Second-order activities are also involved in most of the texts of purely geometrical character that I have been able to gather. Pediasimos wrote scholia to Aristotle's *Posterior Analytics*, one of which presents an exposition of (and a solution to) the problem of duplication of the cube; he appears to draw to a large extent from Philoponos' commentary.[192] Pediasimos also wrote a running commentary on Cleomedes' *Cyclic Theory*, containing some geometrical arguments.[193] Pachymeres prepared a collection of mathematical examples contained in Aristotle's treatises.[194] In a section of his *Paraphrasis of the whole Aristotelian philosophy*, Pachymeres performed one of the "excursions dont il enrichit sa paraphrase": he clarified the difficult passage of the *Meteorology* in which a geometrical proof is presented of the shape of the rainbow.[195] An elementary geometrical construction (a trapezium made of three equilateral triangles) is ascribed to Gregoras in Par. gr. 2345, fol. 118v.[196] A simple[197] geometrical argument is ascribed to Nicholas Cabasilas in Ambros. E 76 sup., fols. 111r–112v. Argyros wrote a short tract on the first stereographic projection employed in Ptolemy's *Geography*;[198] the context is the same as the one that triggered Argyros' Diophantine exercise described above.[199] An anonymous collection of seven geometrical propositions is contained in Par. gr. 2107, fols. 123r–127v; these are three problems half way between geometric metrology and geometry, a problem of construction and three theorems.[200] As for Chortasmenos,

191 Details on all of this in Acerbi, "Isagogic." On Prodromenos' logical collection see Cacouros, "Lexique." Add such mere compilations of definitions and enunciations as the anonymous epitome of *Elements*, Books I–IV, in Par. gr. 2107, fols. 131r–137r (1st half of 15th century).

192 Edition V. De Falco, *In Aristotelis Analytica scholia selecta*, Neapoli 1926, pp. 108.21–120.17.

193 Edition P. Caballero Sánchez, *El* Comentario *de Juan Pediásimo* a los «Cuerpos celestes» de Cleomedes (Nueva Roma 48), Madrid 2018.

194 Edition Heiberg, "Mathematisches," pp. 37–49, from Vindob. phil. gr. 150, fols. 199r–205v, a philosophical miscellany contemporary with Pachymeres.

195 Edition Ruelle, "Deux morceaux." The quotation is from p. 167.

196 Edition in Euclid, *Opera omnia*, vol. 5, ed. Heiberg, pp. 723.13–724.21.

197 But false: it purports to show that the sides of a right-angled triangle are given once its angles are.

198 Edition Laue/Makris, "Isaak Argyros'," and Tsiotras, Ἐξηγητικὴ παράδοση, pp. 428–32. The tract is autograph in Vat. gr. 176, fols. 26v–27r.

199 Cf. *ibidem*, lines 41–45 of the edition. Chortasmenos also transcribes Argyros' tract in his synoptic commentary on Ptolemy's *Geography*: Vat. Urb. gr. 80, fols. 44v–46r.

200 Details in Acerbi, "Problemi."

a text on the measure of the area of a circle is contained in his notebook Vindob. suppl. gr. 75, fols. 276v–277r; in Vat. gr. 208, fols. 227v–230v, some scholia to the *Elements* are in his hand (but the codex is almost entirely in Malachias' hand) and include propositions of the Euclidean treatise organized in deductive schemes.[201] In the same Marc. gr. 301 in which he rearranged the principles of the *Elements*, Plethon provided a remarkable translation in Greek of a method, otherwise attested only in a Latin translation from Arabic, for finding two straight lines mean proportional between assigned straight lines.[202] Four anonymous propositions about shadows are preserved in manuscripts owned by Bessarion and Regiomontanus.[203]

## 7 Geometric Metrology and Geodesy

Both geometric metrology and geodesy adhere to the algorithmic code and for this reason I treat them separately from geometry. The way we may draw a difference between geometric metrology and geodesy (or, as I shall call it later, "fiscal geometry") is that, in principle, the former employs "wrong" prescriptions only when they are approximations—for instance, of the area of a circle—, the latter programmatically reduces all shapes to (degenerate) quadrilaterals and hence resorts in a systematic way to "wrong" prescriptions. Justificatory discourse about geometric metrology not coming from fiscal milieux seems to suggest that it was identified with geometry.[204]

Geometric metrological texts from Greek antiquity are transmitted as collections of paradigmatic problems, usually graded by the complexity of the figure involved, prefaced by or interspersed with generalities about measuring geometrical figures, as well as with lists of relevant shapes (both with an unmistakable Neoplatonic tinge) and of units of measurement. The main collections are contained in ten manuscripts, six of which predate the mid-14th century.[205] As a matter of fact, the expression "geometric metrological corpus"

201 The scholia are edited in Heiberg, "Paralipomena," pp. 350–52; see also *ibidem*, p. 350, for a description of the deductive schemes. Syllogistic schemes of a different kind can be found in Vat. gr. 193, fols. 9r–10v; they cover the proofs of *Elements* I.1–17. Other geometrical elaborations by Chortasmenos can be found among his scholia to Euclid's optical treatises in Vat. gr. 204: see Acerbi, "Byzantine Recensions," n. 108 on pp. 190–91.

202 This is Text 1 in Acerbi/Martinelli Tempesta/Vitrac, "Interventi autografi."

203 These are Marc. gr. 310, fol. 286r–v (an autograph of Bessarion), and Nürnberg, Stadtbibliothek, Cent. V app. 8, fols. 237v, 236r–v (early 15th century).

204 Read for instance the preface of Pediasimos' Σύνοψις, ed. Friedlein, p. 7.4–9.

205 On the structure of the collections and on the manuscripts carrying them see Hero, *Opera omnia*, vol. 4, ed. Heiberg, pp. iv–xxvi; vol. 5, pp. i–cxxvi; Hero, *Metrica*, ed. Acerbi/Vitrac,

can properly be applied only to the collections in Seragl. G.İ.1 (*c.* 960) and in Par. suppl. gr. 387. In this connection, one must not forget, first, that the standard edition of the geometric metrological corpus, namely, vols. 4 and 5 of the Heronian *Opera omnia*, presents these collections dismembered and reassembled to form philological monsters called *Geometrica* and *Stereometrica* I–II; second, that the manuscripts containing them usually feature other textual units, whose separation from the strictly geometric metrological material may be questionable: cases in point are the pseudo-Heronian *Definitiones* and *Rechenbuch*-like elaborations. As we have seen, a florilegium contained in Seragl. G.İ.1, edited partly within *Geometrica* and partly within *Stereometrica* I, mainly comprises the latter kind of elaboration, which in their turn are nothing but problems of Diophantine analysis in fictitious geometric metrological guise.

It is quite clear that most of this material comes from late Greek antiquity, but its highly sectional nature encourages increase by accretion. A case in point is the editorial work that some λαμπρότατος "very illustrious" Patrikios made on *Geometrica* 21.[206] The so-called *Geodesy* is almost certainly a Byzantine collection of excerpts from earlier geometric metrological texts.[207]

A Γεωδαισία *Geodesy*, whose anonymous author is traditionally called "Hero of Byzantium," was written *c.* 938.[208] After a preface and a lacuna involving at least one folio of the common ancestor of the tradition, Vat. gr. 1605,[209] the extant text can be divided into ten sections. Of these, sections 2–6 and 10–11 are reworked excerpts from Hero of Alexandria's *Dioptra*;[210] sections 7–9 contain geometric metrological material from a source not yet identified: circumference and area of a circle (7); surface, volume, and centre of gravity of some standard solids: cube, cylinder, sphere, cone, parallelepiped, pyramid (8); volume of a large water tank (9). In the preface, the author stresses the

pp. 429–588.

206 See Hero, *Metrica*, ed. Acerbi/Vitrac, pp. 450–55 and 507–09. Recall that a *patrikios* Nikephoros was appointed professor of geometry by Constantine VII (r. 913–59): Lemerle, *Le premier*, pp. 264–65.

207 See, for the edition and a discussion, Hero, *Opera omnia*, vol. 5, ed. Heiberg, pp. lxvi–xcvii.

208 Edition Sullivan, *Siegecraft*, pp. 114–52. The date is argued in Martin, *Recherches*, pp. 267–75.

209 The codex dates to the middle 11th century; the *Geodesy* is preceded by a poliorcetic compilation traditionally assigned to the same author (see below).

210 Section 2, height of a distant wall (= *Dioptra* 12); 3–4, distance of inaccessible points (= *Dioptra* 10); 5, position of the straight line joining inaccessible points (= *Dioptra* 10); 6, surface of some plane figures by decomposition into triangles, maybe incomplete (cf. *Dioptra* 23–24); 10, flow of a source (= *Dioptra* 31); 11, angular distance between stars (= *Dioptra* 32). The last two sections contain extensive verbatim excerpts. In section 11 the author refers by title to his own writing Θέσις ἡλιακῶν ὡροσκοπείων *Positioning of Sundials*.

importance of the dioptra for siegecraft and asserts that he will compose a synopsis of previous writings and make abstract theories accessible to the layman. He mentions Euclid, Archimedes, Hero; he quotes definitions 25, 18, 19, 20, 12, 13 of Book XI of the *Elements* and the enunciation of Archimedes' *Measurement of a Circle* 1. The treatise is enriched with beautiful figures, some of which display a realistic touch.

Pediasimos wrote a Σύνοψις περὶ μετρήσεως καὶ μερισμοῦ γῆς *Epitome on land-measuring and land-partitioning*, usually referred to as *Geometry*, dealing with geometric metrological matters, to a large extent made up of extracts from pseudo-Heronian compilations.[211] Pediasimos starts by drawing a distinction between geometry and geodesy, the latter being the discipline concerned with partitioning parcels. He then expounds a classification of points,[212] lines, shapes, and angles relevant to land measurement. "Postulates" and "lemmas" are then stated; these are metrological equivalences, and a mix of arithmetical and geometrical assumptions, respectively. Prescriptions for measuring lines and figures are expounded, according to the following sequence.[213] Area of a square; side of a square of given area (only a *post factum* check); diagonal of a square, with a digression on the several categories of ratios; rectangle, which Pediasimos calls "parallelogram"; equilateral triangle, with a comparison between the methods of Nikomachos (of course applied to a triangular *number*), Hero, and "fiscal geometry": the latter is deemed inadequate, the former two are declared to be compatible, but the final prescription amounts to drawing a height and calculating its length (in such a way that the two residual methods, too, are compatible); triangles: right-angled, isosceles, scalene, generic (Heronian prescription); rhombus, rhomboid; trapezia: right-angled, isosceles, scalene; circular shapes. Compounded shapes are then discussed. Finally, geodesy is treated, with prescriptions for partitioning (not necessarily complex) shapes in simpler ones; the sequence of shapes is the same as above.

A short tract by Argyros,[214] sometimes transmitted in the form of a "letter to Kolybas," deals with the problem of how to measure non-rectangular figures.

211 Edition Pediasimos, *Geometry*.

212 These are cardinal points etc.

213 For most geometrical species, seven examples are given, depending on whether the relevant lengths are expressed in one of the three units of measurement assumed as simple or in the four possible combinations of them.

214 Transcription from a single, and very debased, manuscript in Lefort et al., *Géométries*, pp. 154–58. The two versions of this tract have different titles: πῶς ἂν τὰ μὴ ὀρθὰ τῶν τριγώνων εἰς ὀρθὰ μεταποιήσαιμεν, καὶ περί τινων ἄλλων σχημάτων *How shall we transform the non-right-angled triangles into right-angled, and on some other figures*, and Ἰσαὰκ μοναχοῦ τοῦ Ἀργυροῦ, ὃς ἐν Πιττακίῳ, τῷ Κολυβᾷ ἐν Μιτυλήνῃ ὄντι καὶ τὸ τοιοῦτον αἰτήσαντι· ἔστι δὲ μέθοδος γεωδαισίας, τουτέστι μετρήσεως χωρίων, ἀσφαλής τε καὶ σύντομος; *Of Isaak*

Argyros first provides a definition of a right angle; he shows then, by comparing a square and a rhombus with equal sides, that this property is no guarantee of equality of areas. Triangles are measured by drawing and measuring a height. The final section, about measuring a generic quadrilateral by partition in a central rectangle and a number of peripheral triangles, is not satisfactorily argued, and end with resorting to a prescription typical of the discipline to which I now turn.

A tradition of "fiscal geometry" in the Greek language, of unknown but certainly ancient origin, surfaces in Byzantine times. This we may properly call "geodesy," since it was intended to assist land-surveyors. The texts are organized exactly as geometric metrological collections are: possibly an introduction dealing with generalities about land-surveying and units of measurement, then certainly a series of problems serving as paradigmatic examples, usually graded by the complexity of the figure involved. The corpus of such writings has no real cohesion: they are scattered in a number of (mainly juridical) manuscripts.[215] Moreover, they all are anonymous, with two notable exceptions: a short treatise of someone called "George" and a poem ascribed to Psellos.[216] Structured texts like these usually feature, among the introductory considerations, extracts from geometric metrological compilations; George has long extracts, and even mentions Hero. If one excludes George's and Psellos' writings, a relevant portion of the corpus is contained in manuscripts earlier than the 12th century; moreover, some texts must predate a reform, amounting to a redefinition of a basic unit of measurement, introduced by one of the Byzantine emperors of 11th century called Michael. All in all, about one-third of the corpus certainly predates 1204.

Parcels were imposed depending on their area and on the quality of their soil. The latter parameter was taken into account, in a particular system of imposition, by making a basic unit of measurement a function of the quality of

*Argyros, based in Pittakios, to Kolybas, based in Mitylenes and asking this: 'Is there a method of geodesy, that is, of measuring regions, both unfailing and concise?'* Argyros' writing is followed, in its most ancient witness, by an anonymous Byzantine compilation dealing with metrological matters: synopsis in Hero, *Opera omnia*, vol. 5, ed. Heiberg, pp. ic–cii, edition in Acerbi/Vitrac, "Compilation."

215 Sources in Schilbach, *Quellen*, and Lefort et al., *Géométries* (the latter with a rich discussion, on which I shall rely); analysis of the units of measurement in Schilbach, *Metrologie*. See also Lefort, "Radolibos."

216 Editions in Hero, *Opera omnia*, vol. 5, ed. Heiberg, pp. cv–cvii (only George, and partial but with a complete list of parallel passages in pseudo-Heronian compilations); Schilbach, *Quellen*, pp. 86–92 (partial) and 116–25; Lefort et al., *Géométries*, pp. 136–52 and 184–200, respectively. On Psellos' poem see also Moore, *Iter Psellianum*, POE.58, and the edition in *Michaelis Pselli poemata*, ed. L.G. Westerink, Lipsiae 1992, no. 58.

the soil. What is interesting in "fiscal geometry" is that, for practical reasons, the area of a parcel was estimated by applying a reduced set of standard prescriptions involving relevant linear elements of the parcel. As a matter of fact, all parcels, even triangular ones, were treated as more or less "degenerate" quadrilaterals. Therefore, almost all such estimates are "wrong," and usually lead to an overestimation of the area of a parcel, that increases with the irregularity of its contour but that, however, seldom amounts to more than some ten per cent. This overestimate was partly compensated for by the application of a standard reduction rate, usually ten per cent. There were three basic prescriptions for estimating the area of a region: 1) for irregular parcels, multiply one-fourth of the perimeter by itself; 2) for semi-regular parcels of approximately constant length and appreciably variable width, multiply the former by the arithmetic mean of a number of measures of the latter; 3) for quadrilaterals (and hence triangles), take the product of the arithmetic mean of the opposite sides. The last prescription may be further simplified for isosceles trapezia and for rectangles: just replace one or both arithmetic means by one of the equal sides. The elementary arithmetical operations involved in the prescriptions never go beyond multiplication and halving.

## 8 Optics and Mechanics

In early Byzantium, optics and mechanics were jointly studied in the scholarly circle led by Isidoros of Miletus and Anthemios of Tralles,[217] the architects charged in 532 by Justinian with reconstructing the Church of Hagia Sophia in Constantinople. We have seen above the traces of Isidoros' editorial work on Euclid, Archimedes, and Eutocios; he also commented on Hero of Alexandria's *On Vaultings*; both Hero's and Isidoros' writings are lost. On his side, Anthemios wrote a treatise Περὶ παραδόξων μηχανημάτων *On Surprising Mechanisms*, of which only a fragment is extant. We read in it three propositions explaining how to construct pointwise an elliptical mirror and a parabolic mirror (that is, a burning mirror), and how to build an approximation of a parabolic mirror by means of a number of suitably connected, small plane mirrors. Anthemios' writing was widely read in Byzantium, since it is plundered or mentioned by

217 On Isidoros, see the DSB entry; on Anthemius, Huxley, *Anthemius*. Isidoros' commentary on Hero's *On Vaultings* is mentioned in an interpolated remark in Eutocius' commentary on Archimedes' *On the Sphere and the Cylinder* II.1, cf. Archimedes, *Opera omnia*, vol. 3, ed. Heiberg, p. 84.8–11.

Hero of Byzantium,[218] by the author of the *Anonymi Miscellanea Philosophica*, by John Tzetzes, John Zonaras (*c.* 1140), and Eustathios (d. 1198).[219] Apart from burning mirrors, mathematical optics was given little attention in Byzantium:[220] we have seen that Pachymeres included definitions and propositions from Euclid's *Optics* in the geometric section of his *Quadrivium*; that Chortasmenos annotated Euclid's optical treatises in Vat. gr. 204;[221] and that Chrysoloras collated, in manuscripts he owned, recensions A and B of Euclid's *Optics*. Optics also featured among the scientific treatises translated from Greek into Latin in the mid-12th century Sicily ruled by the Hohenstaufen.[222]

The same circles in Southern Italy might have had access to the Greek text of Hero of Alexandria's *Pneumatics*.[223] Acquaintance with this treatise, as well as with Hero's *Automata*, might explain the presence of mechanical devices making a wonder out of the emperor's throne in the mid-10th century.[224] As seen above, this is the period in which "Hero of Byzantium" lived; he not only composed a *Geodesy*, but the only Byzantine poliorcetic manual paying attention to mechanical issues.[225] As the author himself declares, his writing is a

218 Sullivan, *Siegecraft*, 1.30–31. Hero of Byzantium ascribes the expression "axioms of common notion" to Anthemios, but this syntagm cannot be found in the extant fragment of his writing.

219 See note 176 above and, for a detailed analysis of the last three texts, all dealing with Archimedes' burning mirrors, Acerbi, "Geometri," pp. 196–200. It is likely that Zonaras (in *Epitome historiarum* IX.4) and Eustathios (*Commentary on Homer's Iliad*, ed. Van der Valk, vol. 1, p. 191.6–8, and vol. 2, p. 5.1–7) did not have direct access to Anthemios' treatise.

220 For Byzantine theories of vision see chapter 4 of this volume.

221 The same manuscript was systematically annotated by Sylvester Syropoulos (*PLP* 27217); identification by A. Gioffreda, *per litteras*. Optics is also worth a mention in the list of manuscripts Joseph Bryennios (*PLP* 3257) bequeathed to the Patriarchate in 1421: the indicated contents of two scientific codices nicely fit Par. gr. 2342 and 2461 (early 14th century): Acerbi/Pérez Martín, "Scolii," pp. 115–16.

222 See Haskins, *Studies*, and, most recently, Acerbi/Vuillemin-Diem, *Moerbeke*, ch. 8.4. All such translations are extant; they are: Ptolemy, *Almagest*; Euclid, *Elements*, *Data*, *Optics*, *Catoptrics*.

223 The testimony is in Henry Aristippus' epistle *ad Roboratum*, prefacing his own Latin translation of Plato's *Phaedo* (ed. Minio-Paluello, p. 89.13–14); the allusion is to a *Mechanics*, but the subsequent description obviously fits the *Pneumatics*. In the same passage, Aristippus also mentions Euclid's *Optics*. No surviving manuscript of Hero's *Pneumatics* is as early as the mid-12th century, the earliest witness being Marc. gr. 516 (beginning 14th century): Hero, *Opera omnia*, vol. 1 suppl. Hero's *Pneumatics* is also mentioned by Theodore II Dukas Lascaris (r. 1254–58), *Sermon* VII.144, ed. Krikones, and *Letter* 193.13–14, ed. Festa, p. 240.

224 See Brett, "Automata."

225 No title has manuscript authority. The only independent witness is Vat. gr. 1605. Edition Sullivan, *Siegecraft*, pp. 26–112; a detailed list of all passages borrowed from ancient authors in Martin, *Recherches*, pp. 441–45.

compilation drawing on the poliorcetic treatises of Athenaeus, Biton, Hero of Alexandria, Apollodoros. Since, in his *Geodesy*, Hero of Byzantium repeatedly draws on Hero of Alexandria's *Dioptra*, it can be safely assumed that he used the core of an extant manuscript, namely, Par. suppl. gr. 607 (10th century).[226]

## 9 Assessment

Content- or epistemic-laden categories like "originality," "relevance," or "(dis) continuity" show all their inadequacy when we try to apply them to Byzantine mathematics. We may more appropriately assess it by saying that it is sectional, framing, and embedded.

Byzantine mathematics is *sectional* because it mainly comprises works that do not display a tight deductive structure; as a consequence, they can easily be, or actually are, partitioned in independent sections, or can easily be assembled to generate sectional texts: such are logistic and geometric metrological writings, *Rechenbücher*, primers of any kind (including those to special astronomical "texts" like the *Persian Tables*), scholia, isagogic compilations, compendia like the *Quadrivia*. Even such complex architectures as Metochites' *Abridged Astronomical Elements* and Meliteniotes' *Three Books on Astronomy* are sectional writings. A notable exception is Barlaam's *Logistic*.

Byzantine mathematics is *framing* (and not simply second-order) because it relates, to Greek mathematics and to itself, in the same way as, in a manuscript, a frame-commentary *cum* interlinear glosses relates to the main text: primers elaborate *before*, scholia *above*, compendia *after*; disciplines such as geometric metrology and logistic are explicitly presented as *subordinated* to geometry and arithmetic or astronomy—finally, the appropriation of others' writings continuously reshapes the corpus from *within*, as interlinear glosses do.

Byzantine mathematics is finally deeply *embedded*—as a prestigious further step along the social ladder—in the highest socio-political milieux and in a rhetorical tradition that induces subtle modifications in the stylistic codes inherited from Greek antiquity. These three features are unique to Byzantine mathematics—and make it so fascinating.

226 On Byzantine military treatises and on the manuscript tradition of their Greek sources, see Dain, "Stratégistes" and chapter 12 of this volume.

## Appendix: Contents of Logistic and Arithmetical Writings

c = commentary; q = *Quadrivium*; r = *Rechenbuch*; s = scholium or isolated short text; t = treatise; (*) = number theory is only implicit; marg. = in the margin

| | Genre | Easter Comp. | Number Theory | Sexages. system | Non-Greek numerals | Oper. on fractions |
|---|---|---|---|---|---|---|
| *Prolegomena to the Almagest* | t | | | * | | |
| *Anonymus* 1007 | q | | * | | | |
| *Anonymus* 1183 | r | * | (*) | | | * |
| *Anonymus* 1252 | t | * | | * | * | |
| *Anonymus* 1256 | r | | (*) | | | * |
| *Anonymus* E | r | | (*) | | | |
| Pachymeres, *Quadrivium* | q | | * | * | marg. | |
| Planudes, *Great calculation* | t | * | | * | * | |
| Planudes, *sch. Dioph.* | c | | * | | | |
| *Anonymus* L | r | | (*) | | | * |
| *Anonymus* J | r | | (*) | | | |
| *Anonymus* P | r | | (*) | | | * |
| *Anonymus* 1306 | r | * | (*) | | | * |
| *Anonymi* SG | s | | | | | * |
| Bryennios, *scholia* | s | | | | | |
| Metochites, *Abridged* | t | | | * | | |
| Catrarios, *scholia* | s | | | * | | |
| Barlaam, *Logistic* | t | | * | * | | * |
| Argyros, *Square root* | t | | | | | |
| Argyros/Kydones, *Problems* | s | | * | | | |
| Rhabdas, *Letter to Khatzykes* | t | | | | | |
| Rhabdas, *Letter to Tzav.* | rt | * | (*) | | | * |
| Meliteniotes, *Three Books* | t | | | * | | * |
| *Anonymus* M | t | | | * | | * |
| Kydones, *scholia* | s | | | | | |
| *Anonymus* A | s | | | | | |
| Chortasmenos, *scholia* | st | | * | | | |
| *Anonymus* 1436 | r | | * | | | * |
| *Anonymus* V | r | | (*) | | | * |

| Add. | Subtr. | Mult. | Div. | Square root | Fourth propor. | Interp. | Remov. of ratios |
|---|---|---|---|---|---|---|---|
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APPENDIX: Contents of Logistic and Arithmetical Writings (cont.)

| | Genre | Easter Comp. | Number Theory | Sexages. system | Non-Greek numerals | Oper. on fractions |
|---|---|---|---|---|---|---|
| *Anonymus* U | r | | (*) | | * | * |
| *Anonymus* PS | s | | | | | |
| George of Trebizond, *Introd.* | t | | | * | | |

| Add. | Subtr. | Mult. | Div. | Square root | Fourth propor. | Interp. | Remov. of ratios |
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CHAPTER 4

# Byzantine Theories of Vision

*Katerina Ierodiakonou*

## 1 Introduction

On 29 March 867 Patriarch Photius (*c.* 810–after 893) delivered a sermon in the nave of the cathedral church of Constantinople, Hagia Sophia. The occasion for Photius' sermon was the inauguration of the first mosaic decoration in the church after more than a century of strife over the legitimacy of religious icons. Speaking on the day before Easter, the Patriarch celebrated the depiction of Mary and her son in the apse of Hagia Sophia and denounced the errors of Iconoclasm. In section five of this sermon, Photius turns from his description of the depicted figures to a very different, but obviously relevant subject, the function of the sense of sight and its superiority over the sense of hearing:

> The Virgin is holding the Creator in her arms as an infant. Who is there who would not marvel, more from the sight of it than from the oral report, at the magnitude of the mystery, and would not rise up to laud the ineffable condescension that surpasses all worlds? For even if the one introduces the other, yet the comprehension that comes about through sight is shown in very fact to be far superior to the learning that penetrates through the ears. Has a man lent his ear to a story? Has his intelligence visualized and drawn to itself what he has heard? Then, after judging it with sober attention, he deposits it in his memory. No less—indeed much greater—is the power of sight. For surely, having somehow through the outpouring and effluence of the visual rays touched and encompassed the object, it too sends the form of the thing seen on to the mind, letting it be conveyed from there to the memory for the concentration of unfailing knowledge. Has the mind seen? Has it grasped? Has it visualized? Then it has effortlessly transmitted the imprints to the memory.[1]

1 Photius, *Homilies* (*Homiliae*), ed. B. Laourdas, *Φωτίου ὁμιλίαι*, Thessaloniki 1959, no. 17, pp. 170–71 (transl. C. Mango, *The Homilies of Photius Patriarch of Constantinople*, Cambridge, Mass. 1958, p. 294, slightly modified): Ἡ παρθένος τὸν κτίστην χερσὶν ὡς βρέφος βαστάζει. Τίς καθορῶν ἢ τοῖς ὠσὶ ταῦτα βαλλόμενος οὐ μᾶλλον καταπλαγείη τοῦ μυστηρίου τὸ μέγεθος καὶ πρὸς ὕμνον διαναστaίη τῆς ἀφάτου καὶ λόγους πάντας νικώσης συγκαταβάσεως; εἰ γὰρ καὶ δι' ἀλλήλων ἑκάτερον συνεισάγεται, ἀλλὰ πολὺ προέχειν ἐπὶ τῶν ἔργων αὐτῶν ἐπιδείκνυται τῆς κατὰ τὴν ἀκοὴν εἰσδυομένης

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The Byzantines' belief in the superiority of the sense of sight over that of hearing was inherited from antiquity and was frequently evoked by the supporters of the icons, the Iconophiles, during the Iconoclastic controversy. The power of sight was proclaimed superior to the power of hearing and a visual message to an oral one, because that which is seen is perceived more quickly and distinctly than that which is heard. Hearing was thought of as passive and took place over time, whereas seeing was regarded as active and took place instantaneously. Moreover, as the passage from Photius' sermon makes clear, it is also the cognitive effects of vision and hearing that were directly contrasted. For human beings may use both these senses to obtain information, but the knowledge gained through vision was generally acclaimed to be more secure; the person hearing merely receives an oral report; the person seeing sends out visual rays to grasp the object perceived.

Interestingly enough, Photius also gives us in a brief summary his theory of vision, which undoubtedly follows ancient extramission theories: Visual rays are emitted by our eyes, extend all the way to the visible object and grasp it; the acquired information is then brought to our eyes, from there it is sent to the mind and stored in memory. But extramission theories were not the only ancient accounts of vision available to, and discussed by, the Byzantines. That several competing views remained in contention in Byzantium is clearly suggested, for instance, by Nicholas Mesarites, a late 12th century high ecclesiastical officer and later metropolitan, who composed a description of the church of the Holy Apostles in Constantinople. Among other things in this description, Mesarites includes the topics studied and debated by the medical students at the school of higher learning associated with that particular church; and one of the topics that he lists is "whether we see according to an extramission or an intromission."[2]

Indeed, theories of vision drew the attention of the Byzantines for different reasons depending on their different perspectives: Theologians were interested in supporting their iconophile views by appealing to the superior sense of sight, medical doctors wanted to find out more about the anatomy and

μαθήσεως ἡ διὰ τῆς ὄψεως ἐγγινομένη κατάληψις. Ἔκλινέ τις τὸ οὖς εἰς διήγημα; εἵλκυσε φανταζομένη τὸ ἀκουσθὲν ἡ διάνοια; νηφούσῃ μελέτῃ τὸ κριθὲν τῇ μνήμῃ ἐναπέθετο. Οὐδὲν τούτων ἔλαττον, εἰ μὴ καὶ πολὺ μᾶλλον, κρατεῖ τὰ τῆς ὄψεως· καὶ γὰρ καὶ αὐτή γε δήπου τῇ προχύσει καὶ ἀπορροῇ τῶν ὀπτικῶν ἀκτίνων τὸ ὁρατὸν οἱονεί πως ἐπαφωμένη καὶ περιέπουσα τὸ εἶδος τοῦ ὁραθέντος τῷ ἡγεμονικῷ παραπέμπεται, ἐκεῖθεν διαπορθμευθῆναι διδοῦσα τῇ μνήμῃ πρὸς ἐπιστήμης ἀπλανεστάτης συνάθροισιν. Εἶδεν ὁ νοῦς, ἀντελάβετο, ἐφαντάσθη, τοὺς τύπους ἀκόπως ἐν τῇ μνήμῃ παρεπέμψατο.

2 Nicholas Mesarites, *Description of the Church of Holy Apostles at Constantinople* (*Descriptio ecclesiae SS. Apostolorum*), ed. Downey, p. 917, 42.5: εἰ κατ᾽ ἐκπομπὴν ὁρῶμεν ἢ εἰσπομπήν.

function of the eyes, scholars were intrigued by the ancient philosophical doctrines on vision and its proper object, namely colour, as well as by the optical theories elaborated by the ancient mathematicians. Theories of vision were thus placed in Byzantium, as in most other periods and civilizations, at the intersection of natural philosophy, mathematical optics, and medicine. For the most part, however, it is in connection with Byzantine aesthetics, and in particular in connection with the icons, that modern scholars have investigated this subject.[3] There are very few studies about the physiology of vision or about its role in the acquisition of human knowledge, despite the fact that there is plenty of unexplored material in our surviving sources. So, it still remains to be seen whether the systematic examination of the Byzantines' theories of vision could give us an insight into their conceptions of the structure and functioning of the physical world, and this may prove helpful for our better understanding of the Byzantine civilization.

However, the task of this chapter is more limited. I focus on the writings of some Byzantine authors from the 11th to the 14th century, who have been categorized as theologians, philosophers, astronomers or medical doctors, and who composed commentaries on the relevant Aristotelian treatises, introductory textbooks or small essays on natural philosophy and, more specifically, on vision. In particular, the textual material I draw evidence from is the following (in chronological order):

- Symeon Seth (second half of 11th century), *Synopsis of Inquiries on Nature* (*Conspectus rerum naturalium*), ed. Delatte, pp. 71–73
- Michael Psellos (1018–1076), *On Colours*, ed. Westerink, op. 89
  —, *On the Five Senses*, ed. Westerink, op. 108
  —, *On Sense Perception and it Objects*, ed. O'Meara, op. 8
- Nicephorus Blemmydes (1197–*c.* 1269), *Introduction to Physics* (*Epitome physica*), ed. Wegelin, 1189C–1200A
- Sophonias (13th century), *Paraphrase of Aristotle's On the Soul* (*In Aristotelis libros de anima paraphrasis*), ed. Hayduck, 74.32–84.19
- Nicephorus Choumnos (*c.* 1250/55–1327), *On the Nutritive and the Sensitive Soul*, ed. Chrestou, pp. 87–142
- Nicephorus Gregoras (1293/94–1360/61), *Solutions* (*Solutiones questionum*) ed. Leone, pp. 497–502

There is no doubt that a more comprehensive account of Byzantine theories of vision should also include authors and works from the earlier period. For instance, one should also study John Philoponus' 6th-century commentary on

3 For instance, see James, *Light and Colour in Byzantine Art*; "Colour and Meaning in Byzantium"; Nelson, "To Say and to See."

the second book of Aristotle's *On the Soul*,[4] as well as the treatises on the constitution of human beings by Nemesius of Emesa (late 4th century), Theophilus Protospatharios (probably 7th century), Meletius the Monk (9th century), and Leo the Physician (probably 9th century).[5] These earlier writings constitute possible sources from which later Byzantine scholars acquired their knowledge about ancient theories of vision, regardless of the fact that they probably had access both to the ancient philosophers' texts as well as to those of their commentators. That is to say, the Byzantines were in a position to read, and some of them actually read, Plato's *Timaeus*, Aristotle's *On the Soul* (*De anima*) and *On Sense Perception* (*De sensu et sensibilibus*) together with Alexander of Aphrodisias' (late 2nd–early 3rd century), Themistius' (4th century), and Simplicius' (6th century) commentaries, as well as the Peripatetic treatise *On Colours* (*De coloribus*). They were also influenced by relevant medical texts, such as Galen's (2nd century) *On the Doctrines of Hippocrates and Plato* (*De placitis Hippocratis et Platonis*) and *On the Usefulness of the Parts of the Body* (*De usu partium*). Finally, they made use of ancient works on optics, and in particular of Euclid's *Optics* (*Optica*), which they studied in both ancient recensions. Nevertheless, the actual genealogy of the Byzantines' accounts of vision is by no means clear, since they hardly ever made explicit references to the writings of their predecessors. So, although in some cases it is not particularly difficult to detect the ancient texts used by the Byzantines, it often proves a rather complicate enterprise to specify their sources precisely and to uncover the interrelations among them.

Furthermore, I am perfectly aware that there are more authors and works on the sense of sight even from the period I focus on, here, i.e. from the 11th to the 14th century, like for instance:

- Nicephorus Blemmydes, *On the Soul*, ed. Verhelst, §§ 14–16
- Michael of Ephesus (12th century), *Commentary on Aristotle's On Colours*, ed. Papari

4 John Philoponus, *Commentary on Aristotle's On the Soul* (*In Aristotelis libros de anima commentaria*), ed. M. Hayduck, in *Commentaria in Aristotelem Graeca*, vol. 15, Berlin 1897 (transl. W. Charlton, *Philoponus: On Aristotle On the Soul 2.7–12*, London 2005).

5 Nemesius of Emesa, *On the Nature of Man* (*De natura hominis*), ed. M. Morani, Leipzig 1987 (trans. P.J. van der Eijk/R.W. Sharples, Liverpool 2008); Theophilus Protospatharios, *On the Constitution of the Human Body* (*De corporis humani fabrica libri quinque*), ed. W.A. Greenhill, Oxford 1842; Meletius the Monk, *On the Nature of Man* (*De natura hominis*), ed. J.A. Cramer, in *Anecdota Graeca E codd. manuscriptis bibliothecarum Oxoniensium*, vol. 3, Oxford 1836 (repr. Amsterdam 1963); Leo the Physician, *Epitome on the Nature of Man* (*De natura hominum synopsis*), ed. R. Renehan, in *Corpus Medicorum Graecorum* 10/4, Berlin 1969 (repr. 2017). For information about the theories of vision expounded in these works, see Betancourt, *Sight, Touch, and Imagination in Byzantium*, pp. 65–78.

– John Zacharias Aktouarios (*c.* 1275–*c.* 1328), *On the Activities and Illnesses of the Psychic Pneuma and the Corresponding Mode of Diet* (*De spiritu animali*), ed. Ideler, pp. 327–28

In addition, there are most probably more Byzantine texts on vision among the Greek manuscripts in the libraries all over the world, but they first need to appear in critical editions before they can be carefully studied and appraised.[6]

The main criterion, however, for selecting the specific texts in the above list, is my aim to treat just one of the issues related to theories of vision in Byzantium. For there are many different topics concerning the sense of sight, which are addressed and dealt with in the Byzantine texts from the 11th to the 14th century; for instance, how objects are reflected in mirrors, in what way mixed colours are produced from basic ones, how rainbows are formed.[7] In what follows, though, I want to focus only on the theories that the Byzantines advocated concerning the central issue of how exactly vision functions; in other words, I want to discuss the mechanism of vision and, in particular, the question whether the Byzantine thinkers, being influenced by their ancient predecessors, argued in favour of an extramission or an intromission theory.

But first, let me briefly introduce the ancient theories of vision, whose influence is clearly detectable in the writings of Byzantine scholars.

## 2 The Ancient Inheritance

To start with Plato, there is a central passage in the dialogue *Timaeus* (45b2–d3), in which his extramission theory of vision is aptly summarized. Plato claims that a stream of fire-particles emanates from our eyes and coalesces with daylight in such a way as to form together a homogeneous visual body that extends from our eyes to the objects we see; it thus constitutes, as it were, an extension of our visual organs, and helps us to actively focus on, and be, as it were, in touch with the visible objects. Moreover, Plato defines colour in the *Timaeus* (67c6–7) as a stream of fire-particles emanating from objects; hence, we see when these fire-particles cause in the visual body changes, which are

6 For instance, the paraphrases of Aristotle's *On the Soul* and *On Sense Perception* by Theodore Metochites (1270–1332) are currently edited by B. Bydén for the series *Commentaria in Aristotelem Graeca et Byzantina*.

7 For instance, on mirror images, see Nicephorus Choumnos, *On the Nutritive and the Sensitive Soul*, ed. Chrestou, 114.20–116.25; on basic and mixed colours, see Michael of Ephesus, *Commentary on Aristotle's On Colours*, ed. Papari; on rainbows, see Symeon Seth, *Synopsis of Inquiries on Nature*, ed. Delatte, p. 34; Nicephorus Blemmydes, *Introduction to Physics*, ed. Wegelin, 1199B-1210B.

then transmitted to our eyes and from there to our soul. But is it that the visual body extends all the way to the objects we see, or is it that it meets the fiery effluences of visible objects, i.e. their colour, somewhere midway? It is unclear whether or not the Platonic theory of vision is consistent, in this regard, and contemporary scholars have given prevalence sometimes to its active and sometimes to its passive aspects.[8] Leaving this controversial issue aside, it is also interesting to find out, in what follows, how this theory was understood and interpreted by its Byzantine adherents.

Aristotle differs considerably from Plato in putting forward an intromission theory of vision, at least according to the way he argues in his treatises *On the Soul* (book 2, ch. 7) and *On Sense Perception* (ch. 3). The Aristotelian position is that we see when a certain quality from visible objects, i.e. their colour, is transmitted to our eyes through the instantaneous alteration of the intervening transparent medium, e.g. air or water. That is to say, nothing emanates from our eyes, but we see when our eyes are affected by the objects' colour, which has the power to cause changes to the transparent medium; and this happens only when there is light, which constitutes the actualized state of the transparent medium. The controversial issue among contemporary scholars is how to understand the alteration of the transparent medium as well as of what is transparent in our visual organs, i.e. the water in our eyes. To put it briefly, the issue is whether Aristotle's theory implies that something from coloured objects actually starts a material process affecting the transparent medium—this is the literalist interpretation—, or what rather happens is that the colour only appears through the transparent medium, which thus becomes in a way coloured without undergoing a real alteration—this is the spiritualist or intentionalist interpretation; and there are, of course, alternative interpretations that suggest compromises between these two.[9] I should refrain from entering this debate, here, but it is interesting to examine in Aristotle's case, too, how his theory of vision was received in Byzantium.

Turning next to the Hellenistic schools, Epicurus claims, following in this Democritus, that very fine effluences of atoms, the so-called "*eidola*" (εἴδωλα) and in Latin "*simulacra*," are constantly emitted by the surface of objects and enter our eyes with enormous velocity. Note that, according to the Epicurean intromission theory, these effluences preserve, under normal conditions, the character and configuration of the atoms as found at the surface of objects.

8 For instance, see Remes, "Plato: Interaction Between the External Body and the Perceiver."

9 For instance, see Burnyeat, "How Much Happens When Aristotle Sees Red"; Sorabji "Aristotle on Sensory Processes and Intentionality"; Caston, "The Spirit and the Letter"; Lorenz, "The Assimilation of Sense to Sense-Object."

Thus, when we say that we see the colour of an object, Epicurus thinks that we must be referring to the character and configuration of the atoms transmitted by the *eidola*, which are coloured as much as the objects themselves.

The Stoics, on the other hand, advocate a theory of vision that seems to constitute a further development of Plato's extramission theory. For they also explain vision by suggesting that it involves the formation of a continuous substance between our eyes and the visible object; that is to say, a visual body which is, according to them, in the shape of a cone with its base contiguous to the object we see, and which is often compared in our sources with a walking-stick. There is an important disagreement, however, concerning what the Stoics say about the actual formation of this visual body: Some scholars claim that the innate *pneuma* (πνεῦμα), which stretches from the soul to the eyes, subsequently pours out from the eyes and grasps the visible object, whereas others argue that the air in contact with the pupils, being pierced by the *pneuma*, is instantly conditioned so that it becomes able to register any change of state induced by the state of the object; this state is further communicated to the eyes, and the state of the eyes to the rational part of the soul, without any need for the *pneuma* to exit the eyes. But, again, this is not the occasion to delve into the intricacies of this debate.[10] Besides, the Byzantine theories of vision do not explicitly refer to the Stoics or the Epicureans, though there are aspects of them that seem to be influenced, directly or indirectly, by the Hellenistic developments.

Finally, Galen's theory of vision, as he presents it in his treatises *On the Doctrines of Hippocrates and Plato* and *On the Usefulness of the Parts of the Body*, is rather eclectic, in the sense that it integrates many elements from previous theories.[11] First, though, Galen makes sure to show the inadequacy of his predecessors' doctrines, which he explicitly divides into extramission and intromission theories of vision. He argues against all theories presupposing that something is emitted by the objects we see, be it corporeal or not: According to him, objects do not emit *eidola*. For if the sense of sight depended on *eidola* being emitted, for instance, by a large mountain, they would not be able to enter our eyes or reach at the same time countless perceivers. Also, it is not that we see because a certain quality of objects is instantaneously transmitted through the transparent medium to our eyes. Galen agrees with Aristotle that vision involves the instantaneous alteration of the transparent medium, but he

10 Hahm, "Early Hellenistic Theories of Vision"; Ierodiakonou, "Two Puzzles in Post-Aristotelian Theories of Vision."

11 Boudon-Millot, "Vision and Vision Disorders"; Ierodiakonou, "Galen's Criticism of the Aristotelian Theory of Colour Vision"; "On Galen's Theory of Vision."

accuses him for failing to explain how we come to know the size, the position, and the distance of perceived objects (e.g. *On the Doctrines of Hippocrates and Plato* 7.5.1–3, 452.29–454.4; 7.7.1–5, 470.3–21 De Lacy).

After questioning the Aristotelian and Epicurean theories of vision, Galen expounds his own. He favours the view, and the Platonic and Stoic influence is here clear, that we see because a visual body is formed between our eyes and visible objects. But it is not Plato's fire-particles, according to him, that play the crucial role in the sense of sight. He thinks that what is indispensable in seeing is our innate *pneuma*, although he disagrees with the Stoics that its effect on the surrounding air is such as to create something like a walking-stick extending all the way to the visible object; in his view, when the innate *pneuma* pierces the air, it completely assimilates it to itself (e.g. *On the Doctrines of Hippocrates and Plato* 7.5.5–7, 454.8–16; 7.5.41, 460.28–33; 7.7.20, 474.8–12 De Lacy).

In addition, Galen invokes the model of vision advanced by the ancient mathematicians in their works on optics and catoptrics, according to which visual rays (ὄψεις) are emitted from the eye in the form of a discrete conical fan of straight lines. No role is played by the medium; the visible object is entirely passive, and it is actually seen whenever one or more visual rays touch it. Galen is the first, as far as I know, who attempts to connect the mathematical with the philosophical theories of vision. For instance, in the tenth book of his treatise *On the Usefulness of the Parts of the Body* (3.812–41 Kühn), he devotes a long section to the fundamental elements of a theory of vision based on the assumption of rectilinear rays. After pointing out that most people are ignorant or confused about such a theory, he undertakes to show how the rules of optics are applied by the geometers to the understanding of the sense of sight. Indeed, in this and other occasions, he makes use of Euclid's and Ptolemy's (2nd century) *Optics* as well as of Hero's (1st century) *Catoptrics* (*Catoptrica*), which deal among other things with the relation between the size of visible objects and the angles under which they are seen or the distance from which they are seen.[12]

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12 The basics of the mathematical model of vision are briefly expounded in some definitions of Euclid's *Optics*, and in a preface attached to the so-called recension B of the same treatise. This recension, which is usually but wrongly ascribed to Theon of Alexandria (4th century), sets out among others some arguments supporting the extramission theory and refuting any intromission mechanism. Ptolemy's *Optics* we only read in a Latin translation from the Arabic. For the ancient mathematical theory of vision, see Jones, "Peripatetic and Euclidean Theories of the Visual Ray." For optics in Byzantium, see chapter 3 of this volume.

## 3 The Byzantine Reception

I have presented Galen's theory of vision in more detail than the previous ancient theories, because he seems to have influenced to a great extent the Byzantine thinkers whose works I here examine. In the first place, most of them follow him in dividing the ancient doctrines into extramission and intromission theories of vision, but also in taking into consideration the mathematical model.

Symeon Seth, for instance, devotes some paragraphs of his work *Synopsis of Inquiries on Nature* to the sense of sight, in which he distinguishes the views of the Aristotelians from those of the geometers and of many philosophers.[13] The Aristotelians are reported to have claimed that the air transmits from visible objects to the eyes something to which he refers as "images" (ἰνδάλματα), whereas the geometers and many philosophers talked of rays emitted by our eyes similar to those of the sun; just like the sun's rays illuminate everything as soon as the sun rises, our visual rays pour forth and instantaneously grasp everything as far as the sky. Seth concludes, on the basis of some arguments borrowed by the mathematicians concerning reflection and refraction, that the extramission theory is the correct one. In fact, he explicitly refers to Ptolemaeus' *Optics* and his view that the optical *pneuma* is made of the fifth element.[14]

Two centuries later, Nicephorus Blemmydes, too, distinguishes in his *Introduction to Physics* between the mathematical model of vision and that of the natural philosophers.[15] The mathematicians are again said to have claimed

13 Symeon Seth, *Synopsis of Inquiries on Nature*, ed. Delatte, pp. 71–73: (§ 71.1–15) Περὶ τοῦ πῶς ὁρῶμεν πολλὰς ἔσχον οἱ παλαιοὶ ἀμφιβολίας καὶ ἄμφω τὰ μέρη τοσοῦτον ἕκαστον τὴν ἰδίαν δόξαν ἐκράτυνεν ὡς καὶ τὸν πρῶτον φιλόσοφον ἐπαπορῆσαι τίνι τούτων τὴν νικῶσαν ἐπιψηφίσοιτο. οἱ μὲν οὖν Ἀριστοτελικοὶ ἐδόξασαν ὡς τὰ τῶν ὁρωμένων ἰνδάλματα διαπορθμεύει ὁ ἀὴρ ἐπὶ τὸ κρυσταλλοειδὲς τὸ ἐν τῷ ὀφθαλμῷ καὶ τοῦτο διαφανὲς ὂν δέχεται τὸν τύπον τῶν ὁρατῶν. οἱ δὲ γεωμέτραι καὶ πολλοὶ τῶν φιλοσόφων ἀπεφήναντο ὡς ἀκτῖνές τινες ἐξέρχονται ἐκ τῶν ὀφθαλμῶν καὶ καταλαμβάνουσι τὸ ὁρατόν, παρεικάσαντες ταύτας ταῖς τοῦ ἡλίου ἀκτῖσιν. ὥσπερ γὰρ αὗται ἅμα τῷ τὸν ἥλιον ἀνατεῖλαι ἀχρόνως ἐπιλάμπουσι τοῖς τῆδε, πολλοῦ τοῦ διαστήματος μεταξὺ τῆς γῆς καὶ τοῦ ἡλίου ὄντος, οὕτω καὶ ἡ ἡμετέρα ὄψις ἅμα τῷ ἀναβλέψαι καταλαμβάνει ἀχρόνως τὸν οὐρανόν ... (§ 74.10–14) ἐξ ὧν δῆλον ὡς ὑγιεστέρα ἐστὶν ἡ δόξα ἡ δι' ἀκτίνων ἀπὸ τῶν ὀφθαλμῶν ἐκπεμπομένων πρεσβεύουσα γίνεσθαι τὴν ὅρασιν. φησὶ δὲ ὁ Πτολεμαῖος ἐν τοῖς ὀπτικοῖς ὅτι αἰθερῶδές τί ἐστι καὶ τῆς πέμπτης οὐσίας τὸ ὀπτικὸν πνεῦμα.

14 For information about Symeon Seth's Greek and Arabic sources as well as for a more detailed analysis of his views on the sense of sight, see Bouras-Vallianatos/Xenophontos, "Galen's Reception in Byzantium"; Betancourt, *Sight, Touch, and Imagination in Byzantium*, pp. 78–85.

15 Nicephorus Blemmydes, *Introduction to Physics*, ed. Wegelin, 1192B: Οἱ μὲν γὰρ τῶν μαθημάτων ἀκτῖνάς φασί τινας ἐκχεομένας τῶν ὀφθαλμῶν καὶ προσπιπτούσας τῷ ὁρατῷ τοῦ ὁρᾷν αἰτίας εἶναι ἡμῖν, αὐτὰς δὴ ταύτας ἀπὸ τῶν κατόπτρων καὶ πάντων τῶν τοιούτων

that vision results because visual rays emanate from our eyes and reach the objects we see, whereas the natural philosophers related the mechanism of vision to the qualities emitted by visible objects and transmitted to our eyes through the transparent medium. Note that the Aristotelian view is now presented as the view of the natural philosophers, whereas the extramission theory of vision is identified exclusively with the model introduced by the mathematicians. And we find a similar distinction in Sophonias' paraphrase of Aristotle's *On the Soul*,[16] which has reasonably been said to draw heavily on Blemmydes' textbook.[17] However, there is a difference between the two works that turns out to be of some interest: Sophonias presents the view of the mathematicians, according to which vision is due to rays emitted by our eyes, then the view of the natural philosophers, according to which vision is due to qualities of objects entering our eyes, but at the end he adds a third alternative account of vision not mentioned by Blemmydes; that is, the view of those who think that vision results from "*sunaugeia*" (συναύγεια), i.e. from the coalescence, concurrence, convergence or fusing of rays.

Let me focus briefly on the term "*sunaugeia*," in order to clarify and identify the third alternative theory of vision that Sophonias mentions. After all, this same term is used two more times by Sophonias in his paraphrase,[18] but also once by Blemmydes in his *Introduction to Physics*.[19] In all these cases, the term

ἀνακλωμένας ἐπὶ τὸ ὁρατὸν πρὸς ἴσας γωνίας τὴν αἰτίαν πάλιν ἡμῖν παρέχειν τοῦ ὄντως ὁρᾷν τὸ ὁρώμενον· τοῖς δὲ φυσικοῖς οὐ δοκεῖ δι' ἀκτίνων ἐκπομπῆς τελεῖσθαι τὴν ὅρασιν, ἀλλὰ τῇ εἰσδοχῇ τῆς τῶν ὁρωμένων ποιότητος. Ὁρᾶσθαι γάρ φασι τὰ μὲν εὐθείας ὁρώμενα τῷ πάσχειν ὑπὸ τοῦ ὁρωμένου χρώματος τὸ μεταξὺ τοῦ ὁρωμένου καὶ τῆς ὄψεως διαφανές, καὶ μεταδιδόναι τῇ ὄψει τοῦ πάθους, οὔσῃ καὶ ταύτῃ διαφανεῖ.

16 Sophonias, *Paraphrase of Aristotle's On the Soul*, ed. Hayduck, 75.2–5: πῶς ποτε καὶ τὸ ὁρᾶν γίνεται, πότερον κατά τινων ἀκτίνων σωματικῶν ἐκπομπὴν ἀπὸ τῶν ὀμμάτων, ὥσπερ οἱ μαθηματικοὶ λέγουσιν, ἢ τῇ εἰσδοχῇ τῆς τῶν ὁρωμένων ποιότητος, ὥσπερ οἱ φυσικοί; ἢ ἕτερόν τι μᾶλλον καὶ τρίτον, καὶ τοῦτ᾽ ἔσται δήπου κατὰ συναύγειαν;

17 See Bydén, *Theodore Metochites' Stoicheiosis Astronomike*, p. 205. Bydén cautiously notes that he cannot, of course, exclude the possibility that Blemmydes and Sophonias used an unknown common source.

18 Sophonias, *Paraphrase of Aristotle's On the Soul*, ed. Hayduck, 77.12–22: μήποτ' οὖν ἐξιέναι μέν τι τῶν ὀμμάτων δεῖ λέγειν (τοῦτο δὲ αὐγοειδὲς καὶ ὀπτικὸν πνεῦμα), πρὸς τὴν τῶν ὁρατῶν ἀντίληψιν, μὴ μέντοι καθάπαξ ἀρκεῖν, ὥσπερ οἱ ἀπὸ μαθημάτων λέγουσιν, ἀλλὰ δεῖσθαι καὶ τοῦ ἐκτὸς φωτὸς χειραγωγήσοντος καὶ συναντιληψομένου, καὶ οὕτω κατὰ συναύγειαν τὴν ὄψιν ὁρᾶν. τά τε γὰρ πολλὰ τῶν ἀπόρων ἐν τούτῳ λυθήσεται, καὶ σύμφωνα τοῖς φαινομένοις μᾶλλον ἔσται, εἴπερ τὰ πρότερα. ὅτι μὲν γὰρ ἐξέρχεταί τι τῶν ὀφθαλμῶν, τὸ τῶν ὀπτικῶν νεύρων πρὸς τὰ τῶν ἄλλων αἰσθητηρίων διάφορον παρίστησιν ἐναργῶς. σωλῆνες γὰρ ὥσπερ ταῦτα καὶ πόροι, ναστὰ δέ πως τὰ τῶν ἄλλων καὶ ἄτρητα. οὐχ ὁρῶμεν δὲ ἐν σκότῳ, ὅτι κοινωνίαν δεῖ τῶν φώτων εἶναι καὶ ὅτι κατὰ συναύγειαν τοῖς ὄμμασιν ἡ ἐνέργεια.

19 Nicephorus Blemmydes, *Introduction to Physics*, ed. Wegelin, 1193C-1196C: Καθ᾽αὑτὴν μὲν οὖν ἡ ὄψις οὐκ ἰσχύει μέχρι πολλοῦ διήκειν· ἐμπίπτουσα δὲ τῷ περιέχοντι διαφανεῖ καὶ τῇ πρώτῃ

refers to the coalescence of the innate *pneuma* with daylight, so that the two together form a homogeneous body. In other words, it seems that the third alternative theory of vision, which is described by the term "*sunaugeia*," refers in the works of these two Byzantine thinkers to Galen's theory of vision or, more precisely, to Galen's take on Plato's theory of vision. For although Galen does not favour Plato's fire-particles, he seems to think that he adheres to the Platonic doctrine when he claims that the innate *pneuma* coalesces with daylight in such a way that it instantaneously assimilates the surrounding air, and thus endows it with the ability to see.

Indeed, since Galen's interpretation does not require that effluences from our eyes travel all the way to the objects we see, it manages to defend the Platonic theory from possible objections such as that found as early as in Aristotle's treatise *On Sense Perception* (438a25–27), according to which it would be absurd to think that effluences from our eyes extend to the stars or even to a certain point, where they coalesce with effluences from visible objects. Aristotle does not name his opponents, but his associate Theophrastus (*On the Senses* 5) states clearly that, in Plato's view, effluences from our eyes meet those from visible objects at some point midway. He even remarks that Plato places in this way his theory midway between, on the one hand, theories according to which we see because something from the eyes impinges upon visible objects and, on the other hand, theories according to which we see because something from visible objects is emitted to the eyes. And the same interpretation of Plato's theory as a third alternative to the extramission and intromission theories of vision is to be found in Alexander of Aphrodisias' comments on Aristotle's *On Sense Perception* (27.26–28.15).

In other words, it seems that in antiquity there were two different interpretations of Plato's theory of vision: The Aristotelians offered an interpretation, according to which the visual body coalesces with the effluences from visible objects somewhere between our eyes and the objects we see, whereas Galen put forward a different interpretation, according to which what emanates from our eyes immediately assimilates the surrounding air to itself. Leaving aside

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προσβολῇ τὴν ἀλλοίωσιν ἐργαζομένη διαδίδωσιν ἄχρι πλείστου συνεχοῦς ἑαυτήν, μέχρις ἂν καταλάβοι τὸ ὁρατόν, συνεκτιενομένη τῷ περὶ τὸν μεταξὺ ἀέρα φωτί, καθὰ συγγενεῖ. Ὅτε γὰρ ἀὴρ εὐδιάχυτός τε καὶ εὐαλλοίωτος ὡς οὐδὲν ἕτερον, καὶ ἡ ὄψις καθαρῶς ὑπάρχει φωτοειδής. Καὶ ὅπερ καὶ τοῦ λύχνου φῶς ἐν οἴκῳ δρᾷ σκοτεινῷ (τῇ πρώτῃ γὰρ εἰσόδῳ τὸν ἐν αὐτῷ ἀέρα φωτίζει ὁμοῦ), τοῦτο δὴ καὶ τὴν ὄψιν νοητέον ποιεῖν ἐν τῷ μεταξὺ ταύτης τε καὶ τοῦ ὁρατοῦ πεφωτισμένῳ ἀέρι. Τῇ πρώτῃ γὰρ προσβολῇ τοῦτον ἀλλοιοῦν ἰσχύει, δυναμουμένη τῷ ἐκτὸς φωτὶ καὶ συνεργοῦσα τούτῳ διὰ τὴν οἰκείωσιν. Πολλὴν γὰρ ὅτι τὸ ὀπτικὸν φῶς τὴν οἰκείωσιν ἔχει πρὸς τὸ ἐκτός, κἀκεῖνο πρὸς τὸ τῆς ὄψεως· ὡς ἑκάτερα τὰ φῶτα ζητεῖν ἄλληλα, καὶ ὑπὸ τοῦ ἰσχυροτέρου θάτερον ἕλκεσθαι μὴ ἀντιβαῖνον ὅλως, ἀλλὰ μᾶλλον πρὸς τὴν ὁλκὴν ἐπειγόμενον καὶ πρὸς τὸ συγγενὲς ἀποτεινόμενον φυσικῶς … Οὕτω τοίνυν κατὰ συναύγειαν ἐνεργούσης τῆς ὄψεως …

the question which of the two accounts is more faithful to the Platonic doctrine, it is worth noting, for our purposes, that the term "*sunaugeia*" has also two different meanings parallel to these two interpretations: It refers to the coalescence of the innate *pneuma* with daylight, as we saw in Blemmydes' and Sophonias' texts, but it is also defined as the midway coalescence in daylight of the rays emitted by our eyes with those emitted by visible objects. More specifically, this second meaning of "*sunaugeia*" is used in ancient doxography[20] and in Nemesius' *On the Nature of Man*,[21] in order to characterize Plato's theory of vision, but it is also found in a small essay that Michael Psellos devotes to the five senses; in fact, Psellos goes as far as to anachronistically attribute the term "*sunaugeia*" to Plato himself.[22] Moreover, in another small essay on colours, Psellos explicitly says that, according to Plato's account, effluences from the objects we see coalesce with those from our eyes at some point midway.[23]

Hence, it seems that Psellos adheres to the Aristotelians' interpretation of Plato's theory of vision, whereas Blemmydes and Sophonias are influenced by Galen. And their Galenic inheritance becomes even clearer in some of the arguments we read in Blemmydes' textbook and in Sophonias' paraphrase against intromission theories of vision.[24] For instance, they both state that, if it were the case that a certain quality of visible objects is transmitted to our eyes through the transparent medium, then:

1. the channel-like nerves of our eyes would have been superfluous;

20 Aëtius 4.13.11, 404.14–21: Πλάτων συναύγειαν, τοῦ μὲν ἐκ τῶν ὀφθαλμῶν φωτὸς ἐπὶ ποσὸν ἀπορρέοντος εἰς τὸν ὁμογενῆ ἀέρα, τοῦ δὲ ἀπὸ τῶν σωμάτων ἀντιφερομένου, τοῦ δὲ περὶ τὸν μεταξὺ ἀέρα εὐδιάχυτον ὄντα καὶ εὔτρεπτον συνεντεινομένου τῷ πυρώδει τῆς ὄψεως. αὕτη λέγεται Πλατωνικὴ συναύγεια.

21 Nemesius of Emesa, *On the Nature of Man*, ed. Morani, ch. 7, 58.11–14: Πλάτων δὲ κατὰ συναύγειαν τοῦ μὲν ἐκ τῶν ὀφθαλμῶν φωτὸς ἐπὶ ποσὸν ἀπορρέοντος εἰς τὸν ὁμογενῆ ἀέρα, τοῦ δὲ ἀπὸ τῶν σωμάτων ἀντιφερομένου, τοῦ δὲ περὶ τὸν μεταξὺ ἀέρα εὐδιάχυτον ὄντα καὶ εὔτρεπτον συνεκτεινομένου τῷ πυροειδεῖ τῆς ὄψεως.

22 Michael Psellos, *On the Five Senses*, ed. Westerink, op. 108: Ἡ ὅρασις γίνεται ὅταν τὸ ἀπὸ τῶν ὀφθαλμῶν φῶς ἐκφερόμενον συναντήσῃ τῷ ἀπὸ τῶν σωμάτων ἀπορρέοντι, ὅπερ ὁ Πλάτων ὀνομάζει συναύγειαν.

23 Michael Psellos, *On Colours*, ed. Westerink, op. 89: Χρῶμα ἐστὶν ὁρατὴ ποιότης τῆς τῶν σωμάτων ἐπιφανείας. ὁ δέ γε Πλάτων καινόν τινα τρόπον διερμηνεύει περὶ τῶν χρωμάτων. λέγει δὲ ὅτι καὶ ἀπὸ τῶν ὑποκειμένων σωμάτων καὶ ἀπὸ τῶν ὁρώντων ὀμμάτων ἀπόρροιαί τινες πέμπονται, αἵτινες ἐν τῷ μεταξὺ τοῦ διαστήματος μιγνύμεναι τὰς ἰδέας τῶν χρωμάτων ποιοῦσιν.

24 Nicephorus Blemmydes, *Introduction to Physics*, ed. Wegelin, 1193A-C; Sophonias, *Paraphrase of Aristotle's On the Soul*, ed. Hayduck, 77.2–12. For a more comprehensive account of Blemmydes' and Sophonias' arguments and their sources, see Bydén, *Theodore Metochites' Stoicheiosis Astronomike*, pp. 203–05; Manolova, *Sophonias the Philosopher*, pp. 1–38.

2. we would not have been able to see only in a straight line but in all directions, just as in hearing and smelling;
3. we would not have been able to ascertain the size, for instance, of a large mountain, since it could not have entered our eyes;
4. we would not have been able to distinguish by the sense of sight objects situated closely to each other, since we would have confused their colours and shapes; and
5. we would not have been able to discern the difference in distance of the different objects we see.

Moving forward to the 14th century, we find two Byzantine philosophers who seem, at least at first sight, to diverge from the tradition of their predecessors: The first, Nicephorus Choumnos, professes to have reconciled Plato's and Aristotle's theories of vision; the second, Nicephorus Gregoras, is the only Byzantine thinker who clearly defends an intromission theory.

In the prologue of his treatise *On the Nutritive and the Sensitive Soul*, Choumnos announces his project of harmonization, after giving a brief description of the Platonic and Aristotelian theories of vision:[25] According to Plato, he says, the sense of sight functions through emission, having as its cause the element of fire; according to Aristotle, in contrast, we see when colours impinge upon our eyes through the air and water of the intervening transparent medium and of the eyes. In the main text of his treatise, Choumnos gives again a brief account of the two theories and then discusses some of their previously recognized shortcomings: Plato's doctrine, he says, was unfairly criticized by Aristotle, since Plato never actually stated that something emanates from our eyes and extends all the way to the objects we see; for this would have made instantaneous and simultaneous vision impossible. Aristotle's view, on the other hand, faces a different problem; if something from visible objects were transmitted to the eyes through the transparent medium, it would have been absurd for things of large dimensions as the heavens to enter into our eyes. Choumnos proposes a solution to both difficulties, which is supposed to be in full agreement with Plato's account of vision, while retaining essential elements of Aristotle's theory. He claims that the colours of objects affect the illuminated

25 Nicephorus Choumnos, *On the Nutritive and the Sensitive Soul*, ed. Chrestou, 88.13–24: καὶ γοῦν περὶ ὄψεως Πλάτωνι καὶ Ἀριστοτέλει μὴ τῶν αὐτῶν καὶ ἴσων δεδογμένων, ἀλλὰ δόξης μὲν τοῦ Πλάτωνος οὔσης, κατ᾽ ἐκπομπὴν ταύτην ἐνεργεῖν καὶ τὴν αἰτίαν καὶ ἀρχὴν ἔχειν ἐκ πυρός, τοῦ δ᾽ Ἀριστοτέλους πᾶν τοὐναντίον ἐκ διαφανοῦς ἀέρος καὶ ὕδατος ὁμοίως τῷ ὀφθαλμῷ ἐνόντος, διαφανοῦς καὶ αὐτοῦ ὄντος ταύτην εἶναι, καὶ τῶν χρωμάτων ἐμπιπτόντων αὐτῇ ἐνεργεῖν. προσόντος δ᾽ ἀμφοῖν οὐκ ἀπόρου δή τινος μόνου, ἀλλὰ τά γε καὶ ἀδυνάτου, ὁ λόγος καταλλάττει καὶ εἰς ἓν ἄμφω τὼ δόγματε ἄγει, λύων ἅμα καὶ τὰς ἀπορίας, καὶ τὴν ὄψιν δεικνὺς σαφῶς, ὡς ἔστιν ὀρθῶς ἐνεργοῦσα τὸ ἑαυτῆς.

air and fall upon our eyes, as in the Aristotelian doctrine about the alteration of the transparent medium; at the same time, our eyes emit light that blends with the surrounding air, register the colours of objects and communicate the information to the ruling part of the soul, as in Plato's theory, and thus vision occurs instantaneously.[26] Needless to say, this way of unifying the two ancient theories comes admittedly very close to the Galenic theory of vision, though in Galen's case the Platonic predilection is clearer and there is no explicit intention of a harmonization programme.[27]

Finally, in the second of Gregoras' *Solutions* for Empress Helena Palaiologina, there is a significant shift in the Byzantine map of theories of vision. For, if we leave aside Byzantine works that simply paraphrase Aristotle's relevant writings, such as Psellos' brief comments on Aristotle's treatise *On Sense Perception*,[28] Gregoras is the first Byzantine thinker who chooses to defend an intromission theory and to offer, as he says, a demonstration proving that the sense of sight, just like the sense of hearing, is passive and not active. Some of Gregoras' arguments in favour of this theory are the following:[29]

1. Vision cannot occur instantaneously of things as remote as the moon and the stars.[30]

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26 Nicephorus Choumnos, *On the Nutritive and the Sensitive Soul*, ed. Chrestou, 117.1–24: Οὐ μήν, ἀλλ' ἡμῖν οὕτως Ἀριστοτέλους καὶ Πλάτωνος ὄψεως εἵνεκα ζυγομαχούντων, καὶ κατὰ τοὐναντίον πᾶν τῆς διαφορᾶς αὐτῶν δοκούσης εἶναι, πειρατέον ὡς ἂν οἷόν τε ᾖ, σπουδάσαι καταλλάξαι καὶ ἀγαγεῖν εἰς ἓν τοὺς λόγους, τοῖς ἤδη διηπορημένοις μηκέτι δήπουθεν ἐνισχημένους. τοῦτο δ' ἂν γένοιτο, εἰ τοῖς Πλάτωνι λελεγμένοις, ὡς ἔφη Πλάτων χρησαίμεθα καὶ κατὰ τὸ δοκοῦν ἐκείνῳ, καὶ μὴ τοῖς τοῦ Ἀριστοτέλους κατ' αὐτοῦ προσέξομεν ἐλέγχοις. Οὐ γὰρ δὴ τοῦτο Πλάτων οὔτ' ἐνόμισεν οὔτ' εἴρηκεν, ἀχρόνως εἶναί τινα κίνησιν ἀλλάττουσαν τόπον, οὐδέ γε τὸ ἐκ τῆς ὄψεως ὡρμημένον πῦρ ἢ φῶς ὄν, αὐτὸ δὴ τοῦτο διαβαῖνον ἥκειν μέχρι τῶν ὁρωμένων, ἀλλ' ἐπειδὴ χρῶμα πᾶν ἐν φωτί, σκότους γὰρ οὐδέν ἐστι φαινόμενον τούτων, πληροῖ μὲν ταῦτα τὸν ἀέρα, διαφανῆ ἤδη τῷ φωτὶ γεγενημένον, καὶ αὐτοῖς πεπονθότα τοῖς χρώμασι καὶ κατ' αὐτὰ μορφωθέντα. οὕτω δ' ἀέρος, χρωμάτων καὶ φωτὸς ἐσχηκότος καὶ μέχρις ὀφθαλμῶν ἀφικνουμένου, φῶς αὖθις ἐκεῖθεν ὥσπερ ἐκ λαμπτῆρος προσαυγάσαν, ἐς αὐτὸν ἀέρα διαχεῖται. καὶ τῷ γ' ἐν τούτῳ φωτί, ὡς ἔφη Πλάτων, συμφυέν, ὅλον ὅσον ἐν αὐτῷ καὶ σχῆμα καὶ μόρφωμα καὶ μέγεθος βλέπει καὶ διαβιβάζει τοῦτ' αὖθις πρὸς αἴσθησιν τοῦ ἐντὸς ὄντος καὶ ἡγεμονοῦντος· καὶ γίνεται οὕτως τὸ ὁρᾶν, μηδενὸς ἥκιστα ἐπιδεόμενον χρόνου.

27 On Choumnos' theory of vision, see also Verpeaux, *Nicéphore Choumnos*, pp. 143–45; Bydén, *Theodore Metochites' Stoicheiosis Astronomike*, pp. 206–08; Betancourt, *Sight, Touch, and Imagination in Byzantium*, pp. 45–50.

28 Michael Psellos, *On Sense Perception and its Objects*, ed. O'Meara, op. 8.

29 On Gregoras' second *Solution*, see also Guillard, pp. 220–21; Bydén, *Theodore Metochites' Stoicheiosis Astronomike*, pp. 208–09.

30 Nicephorus Gregoras, *Solutions*, ed. Leone, p. 499, lines 53–60: ἢ φρασάτω μοί τις παρελθὼν πόθεν ἄλλοθεν ἀχρόνως οὑτωσὶ καὶ ἀθρόον ἅμα τῇ πρώτῃ κινήσει τῆς ὄψεως ὁρῶμεν καὶ νοοῦμεν τὰ πλείστοις ἅμα καὶ ἀναριθμήτοις σταδίοις ἀπέχοντα τῶν ὀρέων καὶ ἔτι μᾶλλον σελήνην καὶ ἀστέρας ἐν οὐρανῷ, ὧν τὴν ἀφ' ἡμῶν διάστασιν οὐδ' ἡ τῆς διανοίας ἡμῶν αὐτονομία

2. It is easier to see something in the light when one is in the dark, than to see something in the dark when one is in the light; for the proceeding rays of light set the images of objects in the light in motion and bring them forward.[31]
3. If one stares at other people's eyes, one's own image is seen in their pupils; for the eyes are wet and smooth, and thus suitable to receive the imprints of visible objects.[32]
4. To the claim that eyeglasses come to the aid of old people's sense of sight, because something is emitted from their eyes, one could reply that the reason why eyeglasses help old people is that they mediate and moderate the impact of light.[33]

Unfortunately, I have no plausible explanation why Gregoras abandons Plato's views on vision or, for that matter, their Galenic adaptation, and instead

δύναται μέτρῳ δοῦναί τινι, πρὶν εἰς ἀπειρίαν ἀνενεγκεῖν οὔτε τὴν πρὸς ἐκεῖνα διάβασιν οὔτε τὴν ἐκεῖθεν πρὸς ἡμᾶς αὖθις ἀνάκαμψιν καὶ ἀπαγγελίαν τῆς σφῶν καταλήψεως.

31 Nicephorus Gregoras, *Solutions*, ed. Leone, p. 500, lines 101–10: Ἴσμεν γὰρ ὡς οἷς ἐν σκότει καθῆσθαι συμπίπτει, πολλάκις τούτοις ἀπλανῶς καὶ πόρρωθεν βλέπειν περίεστι τοὺς ἐν φωτί, οἷς δ' ἐν φωτί, τούτοις δὲ τοὐναντίον ἥκιστα πάντων ὁρᾶν τοὺς ἐν σκότει. Αἴτιον δ' ὅτι αἱ τῶν τοῦ φωτὸς ἀκτίνων ἀποχεόμεναι πρόοδοι κινοῦσι μὲν καὶ τὰς τῶν ἐν αὐτῷ τῷ φωτὶ καθημένων εἰκόνας καὶ προωθοῦσιν ἐπὶ τὴν πρόσω κἀκ διαμέτρου θέσιν· κινοῦσι δ' οὖν καὶ τὰς τῶν μεταξὺ κειμένων πραγμάτων ὁποῖά ποτ' ἂν εἴη καὶ ὁπόσα ἐκεῖνα πάσας ὁμοῦ καὶ ἀχρόνως εἰπεῖν ἀναματτόμεναι τὰς ἐκείνων εἰκόνας ὡς ἔτυχον ἔχοντα θέσεώς τε καὶ τάξεως. On the perplexing history of this argument, see Ierodiakonou, "Two Puzzles in Post-Aristotelian Theories of Vision."

32 Nicephorus Gregoras, *Solutions*, ed. Leone, pp. 500–501, lines 111–18: Ἤδη δέ τινες καὶ ἀτενῶς ἐνιδόντες τοῖς ὀφθαλμοῖς τῶν προσομιλούντων μηδεμιᾶς ἐπιπροσθούσης κηλῖδος θεάσαιντ' ἂν ὡς ἐν κατόπτροις καὶ τὴν σφετέραν εἰκόνα ταῖς ἐκείνων ἐντυπουμένην κόραις τῶν ὀφθαλμῶν διὰ τὸ ἐν αὐταῖς ὑγρόν τε καὶ λεῖον φύσιν ἔχον ὡς τὸ εἰκὸς ἐναπομάττεσθαι τοὺς τῶν ἔμπροσθεν χαρακτῆρας, ὡς εἶναι κἀντεῦθεν δῆλον δεκτικὴν τῶν ὁρωμένων γίνεσθαι τὴν ὄψιν καὶ μηδαμῇ διάβασιν τῆς ὄψεως πρὸς τὰ ὁρώμενα.

33 Nicephorus Gregoras, *Solutions*, ed. Leone, p. 501, lines 118–38: Εἰ δέ τινες ἐνστατικώτερον ἐγκαλεῖν ἡμῖν οὐκ ὀκνοῦσι τὴν διὰ τῶν ὑαλίνων ὀφθαλμῶν τοῖς γέρουσιν ἐπινοηθεῖσαν τῇ ὄψει βοήθειαν, εἰς κατάλυσιν δῆθεν τῶν ἐμοὶ λεγομένων ἐνταῦθα προφέροντες, αὐτεγκληματικὴν κἀγὼ τὴν ἀνθυποφορὰν πρὸς ἐκείνους ποιήσομαι. Λελήθασι γὰρ ὧν βούλονται δρῶντες ἀντίπαλα καὶ δοκοῦντες ὠθεῖν ὠθοῦνται μᾶλλον αὐτοὶ τοῖς ναυτιλλομένοις ὁμοίως· οἳ τὰ ἀκάτια καὶ τοὺς λέμβους τῶν λιμένων ἀνάγειν βουλόμενοι κοντοῖς καὶ ξύλοις οἱοισδήτισι τοὺς ἐν τοῖς λιμέσιν ὠθοῦσι προβλῆτας, οὐχ ἵν' ἐκείνους κινήσωσιν, ἀλλ' ἵνα τὴν δυσκίνητον στάσιν ἐκείνων ἀρχὴν τῆς σφετέρας ποιῶσι κινήσεως. Ὡς γὰρ οἱ τὰς ὄψεις νοσοῦντες σκιεροῖς ποθοῦσι καὶ ἀλαμπέσιν ἐνδιατρίβειν χωρίοις μὴ δυνάμενοι τὴν ἀκμὴν τῆς ἡλιακῆς ἀκτῖνος ὑπενεγκεῖν, οὕτω κἀνταῦθα τοῖς διὰ γῆρας ἀμβλυωποῦσι βοήθημα γίνεται κράτιστον τουτὶ τῶν ὑαλίνων ὀφθαλμῶν τὸ μηχάνημα μεσιτεῦον καὶ ἀντιφράττον τὴν ἀθρόαν καὶ διακεχυμένην ἔφοδον τοῦ φωτὸς πλείω πολλῷ φερομένην ἢ ὥστε δύνασθαι φέρειν τοὺς ὀφθαλμούς· οἳ διὰ γῆρας ποθοῦσιν ὅσον τῇ συστολῇ μετριώτερον γίνεται καὶ εὐόριστον ὥσπερ ἔνιοι πολλάκις ἀτενίζειν εἰς ὕψος ἀναγκαζόμενοι, τῇ τῆς σφετέρας χειρὸς μεσιτείᾳ χρῶνται πρὸς ἀντίφραξιν τῆς σφοδρᾶς καὶ ἀταμιεύτου φορᾶς τῆς τοῦ αἰθερίου πυρὸς ἀκτῖνος.

endorses an intromission theory. It is puzzling, moreover, that his theory does not exactly accord with Aristotle's, but seems to resemble in certain regards Epicurus' doctrine. For instance, Gregoras' suggested reason why we see objects in the dark when we are in the light, but not in the reverse order, presupposes the emission of images (εἰκόνες) from visible objects as well as the corporeal character of the light rays, which are said to thrust forward the objects' images; interestingly enough, both these views were advocated by the Epicureans, even though their standard term for such images, namely "*eidola*," is here missing.[34]

## 4 Conclusion

Let me conclude with some general remarks: The Byzantine thinkers, whose writings on theories of vision I have briefly examined, do not all follow the same ancient tradition and do not slavishly copy their ancient predecessors or, for that matter, each other. This does not, of course, imply that they introduce original ideas, though their doctrines about the mechanism of the sense of sight and their respective arguments may differ in interesting ways. It is therefore intriguing, but not always particularly rewarding, to closely study the manner each Byzantine scholar sets and phrases the relevant issues, as well as to try to detect the motivation behind their preferences towards the various ancient theories of vision.

Also, reading these Byzantine texts, someone who is used to studying the ancient theories of vision may be struck by a change in the way the sense of sight is discussed in them. For the Byzantines seem to focus on the empirical applications of such theories considerably more than their eminent forerunners. In fact, they often make remarks suggesting that the reason why they prefer one theory over another is exactly because it manages to explain better their everyday observations. Furthermore, they often introduce a significant amount of novel examples or thought experiments, which are meant to illustrate and support their views. Hence, I think that the systematic collection and analysis of such passages in the Byzantine commentaries, textbooks, and treatises on vision would greatly contribute to a more accurate and comprehensive

34 Bydén (*Theodore Metochites' Stoicheiosis Astronomike*, pp. 208–09) lists another argument in which Gregoras seems, again, to put forward a corporealist view of light (*Solutions*, ed. Leone, p. 499, lines 63–81). Still, he argues that Gregoras follows Aristotle's intromission theory, even though he characterizes him as "the fiercest critic of Aristotle in Byzantium," but wonders whether this particular argument is compatible with the Aristotelian account of vision Gregoras defends.

account of the distinctive character and development of the Byzantines' theories of vision.[35]

## Acknowledgments

Byzantine theories of vision have not been at the centre of interest in contemporary studies on Byzantine philosophy. This chapter owes a lot (i) to the chapter on sight in Börje Bydén's *Theodore Metochites' Stoicheiosis Astronomike*, pp. 199–210; and (ii) to the texts and bibliography collected by Sergei Mariev for a seminar at the University of Munich in 2010 on the reception of ancient theories of vision in Byzantium. Roland Betancourt's book *Sight, Touch, and Imagination in Byzantium* came to my attention after having given talks on this topic in the Sorbonne (2013), the University of Berkeley (2016), and the University of Munich (2017); there is an abundance of helpful information and plenty of insightful comments in Betancourt's book, but its scope differs from that of the present chapter. Finally, I would like to thank Fabio Acerbi for his careful reading of this chapter, his constructive remarks, and especially his invaluable suggestions concerning the ancient mathematical model of vision.

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CHAPTER 5

# Meteorology and Physics in Byzantium

*Ioannis Telelis*

## 1 Introduction

In terms of modern scientific conceptions, meteorology and physics are both disciplines of the physical sciences. Modern physical science is ordinarily thought of as the systematic study of the inorganic world, and it is distinct from the study of the organic realm, which is the field of the biological sciences.[1] In this sense, modern physics (together with astronomy and chemistry) is a core research area of the physical sciences, while meteorology—in terms of current scientific classification schemes—is a subfield of earth sciences,[2] which is a further broad research area of modern physical science. Therefore, as part of modern earth sciences, meteorology is defined as the interdisciplinary scientific study of the atmosphere and its phenomena. Nowadays, meteorology is implemented through the quantification of field measurements, and the correlation of the data obtained with certain variables determined by the earth's atmosphere (temperature, air pressure, moisture, and wind flow) on various time scales. Furthermore, the description and prediction of the state of the atmosphere (weather), as well as of the long-term manifestations of weather (climate) on various spatial and temporal scales through the application of mathematical-statistical models, are important topics within modern meteorology.[3] On the other hand, because of the recognition of nature's forces as interrelated and interconvertible forms of energy and the resulting changes in the theoretical conceptions of the philosophy of science, modern

1 For an outlook of the general principles and fields of modern physical science, see Marion, *Physical science in the modern world*, pp. 1–5, especially Figure 1.1.

2 Modern earth sciences (geosciences) is a huge scientific field. It embraces the study of Earth's major spheres in special sub-disciplines: Atmosphere (atmospheric chemistry, meteorology, paleoclimatology), Biosphere (biogeography, paleontology), Hydrosphere (hydrology, limnology, oceanography), Lithosphere (geosphere, geology), Pedosphere (soil science), Environmental systems (environmental science, geography), and others (geodesy and surveying, cartography). For a comprehensive presentation of the variety of disciplines that make up the all-embracing field of geoscience, see the topics presented in: Spellman/Stoudt, *The handbook of geoscience*, pp. v–xi.

3 The variety and complexity of the themes that modern meteorology deals with are well presented in: Ahrens/Henson, *Meteorology today*, pp. xi–xvi.

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physics are defined as scientific research into notions such as motion, force, energy, matter, heat, sound, light, and the components of atoms. Thus, modern research on these topics combines several traditional scientific disciplines of the physical sciences (e.g. classical mechanics, optics, acoustics, electricity, magnetism, heat and matter research) with newly discovered fields of research (electromagnetism, special relativity, quantum theory, atomic physics, statistical theory of matter).[4]

Meteorology and physics gradually reached their current state as disciplines no earlier than the mid-19th century. The consolidation of these disciplines in their modern mathematically-oriented form was the result of epistemological processes associated with technological innovation and advances in the philosophy of science that occurred during the emergence of modern physical science around the end of the Renaissance.[5] Until then, pre-modern meteorology and physics were basic fields of scientific inquiry closely related to philosophy.

In Greco-Roman antiquity and the subsequent medieval period, philosophy and science were linked. Natural philosophy was the broad field of premodern philosophical studies that encompassed the phenomena of the natural world, and sought to uncover the physical causes of the natural processes lying behind them.[6] Within this framework, the concept of meteorology and physics in antiquity and the middle ages did not coincide with what we define nowadays as "meteorology" and "physics." Ancient and medieval physics was much more comprehensive than the modern—technologically influenced—vast scientific discipline, and equated with what natural philosophy explored. Likewise, meteorology was conceived as part of ancient and medieval physics with a scope that exceeded the boundaries of the specialized field of modern meteorology (i.e. the study of atmospheric phenomena and climate), and included topics that are nowadays considered more proper to astronomy, physical geography, geology, or even chemical technology.[7]

One of the most important ancient thinkers in the history of philosophy and science was Aristotle, who created a model for the discipline of natural philosophy together with theoretical tools that influenced the development of scientific inquiry for the subsequent two thousand years. Within the framing

4 See the topics of modern physics discussed in: Becchi/D'Elia, *Introduction to the basic concepts of modern physics*, pp. 1–237.

5 The rise of the mathematical and experimental approach to the understanding of the natural world from the 16th to the end of the 17th century is described in: Henry, *The scientific revolution and the origins of modern science*, pp. 14–53.

6 Grant, *A history of natural philosophy*, p. 8.

7 Vogel, "Byzantine Science," pp. 280–81.

contribution of Aristotle in natural philosophy, theoretical meteorology gained its comprehensive, organized, and systematic character as a scientific intellectual enterprise and part of physics. The content and concepts that governed meteorology and physics from ancient times to the emergence of modern physical science around the end of the Renaissance, were constituted and dominated by Aristotelian doctrines.

The following sections of this chapter offer an overview of meteorology and physics in Byzantium by approaching the two scientific disciplines mainly in their Aristotelian conception. This means that "meteorology" in Byzantium was conceived primarily as the inquiry by Byzantine thinkers into phenomena that take place in the Aristotelian "sublunary sphere" and, up to a degree, overlap with subject matter of modern meteorology (e.g. the explanation of the causes of meteorological phenomena, discussion of climate and its change, and weather prognostication). On the other hand, "physics" is conceived of as a branch of ancient natural philosophy, and is thought to be the survival of Aristotelian physics in Byzantium, namely as the inquiry into the natural behaviour of bodies, insofar as that behaviour corresponds to the study of the principles that govern motion and change of natural bodies, as well as the causes of motion and change per se.[8] Therefore, since the importance of Aristotle's influence on the history of meteorology and physics was significant, a succinct review of pre- and post-Aristotelian doctrines that influenced concepts of meteorology and physics in Byzantium is necessary, with an emphasis on theories systematically elaborated by Greek commentators of late antiquity. In parallel, Aristotelian meteorology and physics had a fundamental influence not only on the philosophy of the early Byzantine period, but also on the Christian-Patristic theological thought. Traces of this influence are also explored. Furthermore, theoretical-philosophical explanations of natural phenomena were not the only way of organizing meteorological knowledge in Byzantium. The well-structured system of Aristotelian theoretical meteorological doctrine survived in parallel with a rich weather lore tradition, which had deep roots in Greek and Roman antiquity. Information on weather prognostication practices constituted a "pseudo-scientific" corpus of meteorological knowledge that remained vivid in various popular Byzantine texts of a practical character. This facet of Byzantine meteorology is also briefly presented. Finally, the revival of scholarly interest in topics related to theoretical meteorology and physics in 11th century Byzantium as well as during the Palaiologan period (13th–15th century) will also be discussed. The rediscovery by scholars of Aristotelian meteorology and physics in the late Byzantine

8 For this approach, see Vogel, *ibidem*, p. 279–82.

period demonstrates a general intellectual trend at that time to approach the study of nature with rational models delivered through Aristotelian natural philosophy.[9]

## 2 Meteorology and Physics: the Inheritance of Antiquity

Natural philosophers of Greek and Roman antiquity investigated the causes of natural processes and attempted to explain the perceptible phenomena of the physical world. In the field of meteorology, Aristotle (384–322 BCE) was the first to offer comprehensive and systematic studies of natural philosophy, both with regard to scientific meteorology and to the science of physics, by engaging his own views with those of his predecessors. Aristotle's doctrines on meteorology and physics were influential for natural philosophers of Greek and Roman antiquity. These doctrines were later transmitted into Byzantium.[10]

### 2.1 *Aristotle's* Meteorology

Aristotle's *Meteorologica* (Meteorology)[11] is the earliest extant Greek work that systematically classifies, describes and interprets the "meteors" (μετέωρα),[12] i.e. the "lofty" phenomena that take place in the sublunary realm. As part of a larger inquiry into natural philosophy, the four books of *Meteorologica* follow on from Aristotle's study of natural motion in *Physica* (Physics), of astronomy in the *De caelo* (On the heavens), of the discussion of the four elements in the *De generatione et corruptione* (On generation and corruption) and preceded by the study of animals and plants. *Meteorologica* encompasses a variety of topics: The structure of the atmosphere and the dual exhalation (I.1–3); phenomena in the upper atmosphere, i.e. burning flames, shooting stars, torches, "goats" (I.4), the Aurora Borealis (I.5), comets (1,6–7), the Milky Way (1.8); phenomena in the lower atmosphere due to moisture, i.e. rain, cloud, and mist (I.9), dew and hoar-frost (I.10), snow (I.11), hail (I.12); winds, rivers, springs

9 The article of Lackner, "Die aristotelische Meteorologie in Byzanz," pp. 639–43 remains fundamental for the study of the reception of Aristotelian meteorology in Byzantium.

10 For concepts on meteorology and physics in Greek antiquity, see Fritscher, "Meteorologie. II. Klassische Antike," pp. 88–93; Heinemann, "Physik," pp. 990–97.

11 Aristotle, *Meteorology*, ed. & transl. Lee. For an analysis of the treatise's content, method, and structure, see Wilson, *Structure and method in Aristotle's Meteorologica*, parts I and II.

12 On the term μετεωρολογία as denoting the relevant scientific discipline in antiquity, see Capelle, "Μετέωρος—μετεωρολογία," pp. 414–48. For a review of the different Greek words related to the topics of ancient meteorology through their precise meaning, their etymology and their possible semantic evolution, see Casevitz, "Les mots grecs de la météorologie," pp. 27–33.

(I.13); the inhabitable regions of the earth, climatic and coastal changes (I.14); the source and saltiness of the sea (II.1–3); winds again (II.4–6); earthquakes and volcanoes (II.7–8); thunder and lightning (II.9); hurricanes, whirlwinds and thunderbolts (III.1); haloes (III.2–3); rainbows (III.4–5); mock-suns and rods (III.6).[13] *Meteorologica* IV is devoted to exhalations within the earth.[14]

In the modern sense, the topics analysed in Aristotle's *Meteorologica* may be considered as being heterogeneous; some of them are classified nowadays as atmospheric phenomena investigated through the discipline of modern meteorology, the others are topics of modern astronomy and seismology. Yet, we also find geometrical discussions about haloes and rainbows, which belong to the field of optics. As such they are more appropriately studied under geometry. Nevertheless, Aristotelian meteorological doctrine is part of a system of cosmological knowledge. Aristotle's main concern in *Meteorologica* was to distinguish and explain all those phenomena lying outside the perfect domain of the heavenly spheres.[15] Since most phenomena that take place in the sublunary realm are associated with the exchange between air and water—two of the four elements that are mostly susceptible to alteration—in *Meteorologica* Aristotle manages to explain them through a physical mechanism. That mechanism is the action of dual exhalation (ἀναθυμίασις).

The mechanism of dual exhalation is a fundamental explanatory theory upon which the system of Aristotelian meteorology is based. Most phenomena presented and analysed in *Meteorologica* are causally connected with the action of the two exhalations. The exhalations are ingredients of the composition of the layers surrounding the earth. Because earth and water are in and around the centre of the universe, two exhalations are dissolved from them by the heat of the sun: (i) a dry exhalation, which is windy (πνευματώδης) and smoky (καπνώδης), is dissolved from the earth, (ii) a moist exhalation (ἀτμιδώδης), also

13 Solmsen, *Aristotle's system of the physical world*, pp. 393–401.

14 *Meteorologica* book IV has a completely different focus compared with the other three books of the work. It provides an account of the qualitative changes of matter and properties of the "homoeomerous" bodies, as well as a discussion of the formation of minerals and metals. For this reason, *Meteorologica* IV is conceived as a chemical treatise the authenticity of which has been disputed since antiquity; see Pepe, "Motivi centrali del IV Libro dei 'Meteorologica,'" pp. 17–34, and Dye, "Remarques sur le livre IV des Météorologiques," pp. 305–15. *Meteorologica* book IV and its influence on Byzantine science is beyond the scope of this chapter, since its subject matter is more appropriate to the discipline of chemistry.

15 Aristotle conceived of the universe as a sequence of concentric spheres (or layers). The outermost sphere, which contained the heavenly bodies, was composed of the incorruptible, immutable, rotating element "aether" (αἰθήρ) (*De caelo* I.2–4); see also Hankinson, *Cause and explanation in ancient Greek thought*, p. 181.

called "vapour" (ἀτμίς), which is naturally humid and warm. Both exhalations move upwards, but the dry exhalation moves further upwards than the moist one. Around the body of earth and water there is the layer of air, which is a mixture of dry and moist exhalation. This is the region where clouds, rain, etc. (from the moist exhalation) and winds (from the dry exhalation) are formed. Around the air lies the sublunary layer, adjacent to the celestial sphere, which is filled with the hot and dry exhalation. This region consists in fact of dry exhalation, which is a kind of fire—not real fire, but an inflammable hot material (ὑπέκκαυμα)—that is easily ignited. This layer is the place where comets, shooting stars, etc. are formed.[16]

### 2.2 *Aristotle's Predecessors*

In *Meteorologica*, Aristotle developed not only his own ideas concerning the phenomena of the sublunary realm, but also concepts from his predecessors as well. At different points throughout this work, Aristotle deliberately correlates his ideas with those of Presocratic philosophers, whose writings do not survive. Even Aristotle's mechanics of the dual exhalation were inherited and adapted from the Presocratic tradition.[17] Presocratics introduced a naturalistic cosmology by explaining natural and meteorological phenomena based on the properties of natural substances. Thales (624–546 BCE) started this tradition and explained earthquakes as the consequence of sea ripples. Anaximander (d. 545 BCE) explained the occurrence of meteorological phenomena, such as thunder, lightning, thunderbolts, whirlwinds, and typhoons, by air (wind in clouds). Anaximenes (585–528 BCE) offered a systematic theory of change as the explanation of these same phenomena by positing a mechanism of variations in pressure, which produced different states of air. Xenophanes (*c.* 570–*c.* 475 BCE) introduced naturalistic explanations of meteorological phenomena (e.g. the rainbow) based on a theory about clouds; the sun, the moon and all luminous celestial phenomena are clouds fed by exhalations arising from the Earth and travelling across the sky until they expire. Empedocles (*c.* 490.–*c.* 430 BCE) constructed the fundamental theory of the four elemental bodies (earth,

16 Aristotle, *Meteorologica*, I.3 (340b19–29), and I.4 (341b6–18). For an analysis of the physical mechanism of the dual exhalation, see Wilson, *Structure and method in Aristotle's Meteorologica* pp. 35–72.

17 Aristotle innovated regarding the mechanics of the dual exhalation by updating theories of Empedocles, Anaxagoras, and Democritus. Moreover, Aristotle owes the concept of the dry exhalation to Heraclitus, who alone among the Presocratics recognized both; see *ibidem*, pp. 51–62.

air/aether, fire and water) that make up the world through combination, separation, and recombination in various proportions.[18]

### 2.3 *Post-Aristotelian Meteorology*

Aristotle's *Meteorologica* books I–III, inaugurated a tradition in the scientific approach to meteorological topics, which was continued in later centuries and was inherited by Byzantium. Pseudo-Aristotle's *De mundo* (On the cosmos) (1st century CE) treats meteorological topics as part of a larger discussion of the universe, rooted in Aristotelian philosophy.[19] Aëtius' *Placita philosophorum* (On the physical doctrines held by the philosophers) (1st century CE) is concerned with presenting views of earlier thinkers and betrays a strong dependence on Aristotelian meteorology in the range and order of its meteorological topics.[20] Pliny the Elder (1st century CE), in his *Naturalis historia* (Natural history), offers a different division of astronomical and meteorological phenomena than that found in Aristotle, Pseudo-Aristotle and Aëtius.[21] Seneca (1st century CE), in his *Naturales quaestiones* (Natural questions) divides the inquiry of natural phenomena into three levels of study: the *caelestia* (heavenly things), the *sublimia* ('lofty' things) and the *terrena* (earthly things), following the Stoic and Aristotelian tradition in meteorology.[22] Diogenes Laërtius (3th century CE), in his *Vitae philosophorum* (Lives and opinions of eminent philosophers), offers an overview of Stoic theories on meteors, which corresponds almost exactly with that of Seneca's *sublimia*.[23] The *Syriac meteorology* covers a smaller range of topics compared with those discussed in previous meteorologies.[24] Epicurus' *Epistula ad Pythoclem* (Letter to Pythocles), as delivered by Diogenes Laërtius (fl. *c.* 3rd century CE), covers not only meteorological, but also cosmological and astronomical topics and departs from Aristotle's strict distinction between astronomical and atmospherical phenomena in the organization of his material. Furthermore, the method of multiple explanations developed in

18 Keyser/Irby-Massie, *Encyclopedia of ancient natural scientists*, passim, articles: "Thalēs of Milētos," "Anaximandros of Milētos," "Anaximenēs of Milētos," "Xenophanēs of Kolophōn," "Empedoklēs of Akragas."

19 Taub, *Ancient meteorology*, pp. 161–68.

20 Aëtius' *Placita* text is reconstructed from Pseudo-Plutarch's *Placita* and Stobaeus' *Eclogae Physicae*; see Mansfeld/Runia, *Aëtiana*, pp. 274–89.

21 Taub, *ibidem*, pp. 179–87.

22 *Ibidem*, pp. 141–61.

23 *Ibidem*, p. 137.

24 This meteorological treatise is preserved in a Syriac-Arabic translation of *c.* 1400 CE, and is identified by many researchers as Theophrastus' (371–287 BCE) lost two-book treatise *Μεταρσιολογικά*. For a discussion on this authorship, see Bakker, *Epicurean meteorology*, pp. 70–73 and pp. 106–8.

Epicurus' *Epistula ad Pythoclem* is opposed to the idea of a unified explanatory principle, such as we find in the works of most natural philosophers, including Aristotle.[25] Lucretius' (1st century CE) didactic poem *De rerum natura* (On the nature of things) discusses celestial, meteorological, and terrestrial phenomena, and attempts to offer multiple rational explanations for their causes aiming at eliminating the search for supernatural ones.[26]

### 2.4 *Weather Prediction and Weather Lore*

Natural philosophy was not the only domain of meteorological inquiry in ancient times. In addition, a parallel—but sometimes intersecting—large cycle of meteorological knowledge focussing on weather prediction was developed. Weather signs and prognostications were matters that attracted much interest during antiquity. Since ancient times a considerable literature on weather prognostication techniques had emerged. This had been cultivated by philosophers in parallel with theoretical meteorology, even though Presocratics, Aristotle, and Theophrastus had given it less scholarly attention.

The variety of works communicating information about meteorological prediction is striking, and includes writings in several literary forms. In Hesiod's didactic poetry (6th century BCE), we find references to weather signs that functioned as a starting point for material of this sort in later Greek and Latin literature.[27] Ancient testimonies report that Democritus, among Presocratics, was interested in and wrote on ways to predict the weather.[28] Furthermore, apart from traces of weather lore included in treatises of theoretical meteorology, such as Aristotle's *Meteorologica* and Theophrastus' *De ventis* (On winds), Theophrastus in his *De signis* (On weather signs), as well as several other authors in Greek and Roman antiquity dealt with portents and deduced meteorological prognoses from the observation of the stars, of living organisms, or other natural processes.[29] This ancient weather lore literature created

25 *Ibidem*, pp. 92–95.

26 Zehnaker, "La météorologie dans les *Questions Naturelles* de Sénèque," pp. 379–454.

27 See Sider/Brunschön, *Theophrastus of Eresus. On weather signs*, p. 6.

28 *Ibidem*, pp. 7–9.

29 Greek and Roman authors who wrote on weather portents and signs: Eudoxos of Knidos (4th century BCE), Bolos of Mendes (3rd century BCE), Aratos (3rd century BCE), Poseidippos (3rd century BCE), Nigidius Figulus (1st century BCE), Varro Reatinus (1st century BCE), Vergil (1st century BCE), Lucan (1st century BCE), Pliny the Elder (1st century BCE), Geminus (1st century CE), Columella (1st century CE), Dionysios the Periegete (2nd century CE), Ptolemy in *Apotelesmatica* (Tetrabiblos) (1st–2nd century CE), Aelian (2nd–3rd century CE), Vegetius (4th–5th century CE) and others. For a survey of the Greek and Roman texts on weather prognostication, see Sider/Brunschön, *ibidem*,

a fundamental background of pseudo-scientific meteorological knowledge, which was later transmitted into the Byzantine culture.

### 2.5 *Aristotle's* Physics

Aristotle's books *Physica*, *De generatione et corruptione*, *De caelo*, and *Meteorologica* include the doctrines of the philosopher on natural philosophy, i.e. the philosophy that deals with the explanation of the non-biological phenomena of the universe. Specifically, Aristotle's *Physica* offers an inquiry into nature (φύσις) itself and the objects of it, in so far as these objects reveal their internal nature, which is governed by the principle of their motion. In other words, *Physica* focuses on the comprehensive understanding of natural things by way of getting to know their principles (ἀρχαί), causes (αἴτια), and elements (στοιχεῖα). Aristotle in the *Physica* develops his theory about the nature of natural things, and sets up subsequent discussions about fundamental principles concerning change (infinity, place, void, and time) by reviewing simultaneously opinions of previous thinkers, such as Parmenides, Melissus, Anaxagoras, Pythagoreans, Zenon, Plato, etc. These discussions included assertions about and solutions to physical problems that would be supported or rejected by later thinkers. For example, the doctrine of motion—including the notion of "resistance to anything that surrounds or besets another" (ἀντιπερίστασις), i.e. the mutual replacement of material, to explain locomotion—led Aristotle to deny the existence of the void. Aristotle supported the view that the void could not exist, since objects should move with infinite speed within it; but he did not believe that actual infinity could exist.[30] Certain tenets of Aristotle's doctrines on motion were criticized or rejected in the Byzantine period, principally by Greek commentators on his work in the 6th century AD (see the next section).

## 3 Meteorology and Physics in the Greek Commentary Tradition

In late antiquity, Aristotle was dominant in the field of natural philosophy, as Plato was the main source of ideas in theology. The Greek commentators on Aristotle played an essential role in the transmission of Aristotle's concepts about natural philosophy into the Byzantine world. In their detailed commentaries,

pp. 11–27. The meteorological interpretations of ancient weather lore are discussed in: Cronin, *Greek popular meteorology from antiquity to the present*, pp. 63–367.

30 For a detailed presentation of the arguments developed in Aristotle's *Physica*, see Aristotle, *Physics*, transl. Waterfield, pp. xvi–lxxiii.

the Greek writers discussed, criticized or, sometimes, creatively transformed the doctrines of Plato and Aristotle, and suggested different answers to same questions.[31] In the fields of meteorology and physics, scholars of the Peripatetic philosophical school of Athens, and the Neoplatonists of the school of Alexandria contributed significantly by transmitting Aristotelian knowledge in those fields.[32] These philosophers produced exhaustive commentaries on Aristotle's *Meteorologica* and *Physica*, by means of which Aristotelian doctrines of both disciplines were approached in a systematic and creative way.[33] These commentaries played an important role in the reception of natural philosophy—as laid down by Aristotle—not only in Byzantium, but also in the Arab and Latin worlds.

### 3.1 *Meteorology*

Aristotle's *Meteorologica* was commented on by Alexander of Aphrodisias (2nd century CE), John Philoponus (*c.* 490–570), and Olympiodorus (*c.* 500–*c.* 564/5). Alexander of Aphrodisias represented the Athenian Peripatetic philosophical school. He produced detailed commentaries on Aristotelian works, which inspired not only the 6th century Neoplatonic commentators of Alexandria in their philosophical inquiry, but also Byzantine scholars in later centuries. Alexander's commentary on Aristotle's *Meteorologica* mostly gives a faithful rendering of Aristotle's text, even though it includes criticism of Aristotle's explanation of why wind moves horizontally along the surface of the earth, or draws on Theophrastus' explanation of the formation of precipitation and of the halo.[34] From the side of the Alexandria Neoplatonist philosophical school, John Philoponus' incomplete extant commentary on Aristotle's *Meteorologica* presents many departures and digressions from Aristotle's arguments, probably influenced by his own polemic against Aristotle.[35] Philoponus criticizes Aristotle's view that the sun is not hot and that it heats the earth by the

31 This tradition goes back to Andronicus of Rhodes (*c.* 50 BCE) and lasted into the Byzantine period almost without interruptions; see Tuominen, "Philosophy of the Ancient Commentators on Aristotle," pp. 852–95.

32 For the differences between the two philosophical schools, see *ibidem*, p. 855, and Chiaradonna/ Trabattoni, *Physics and Philosophy of Nature in Greek Neoplatonism*.

33 For detailed bibliographic references to editions of the texts of Greek commentators of Aristotle in the monumental series *Commentaria in Aristotelem Graeca*, and for current English translations in the series *Ancient Commentators on Aristotle* (general editor: R. Sorabji); see *ibidem*, pp. 869–82.

34 Lettinck, *Aristotle's Meteorology and its reception in the Arab world*, pp. 22–23, p. 100, and p. 252 respectively.

35 On Philoponus' polemic against Aristotle, see Sorabji, *Philoponus and the Rejection of Aristotelian Science*.

motion of its sphere through friction with the sublunary sphere. Philoponus departed also from Aristotle's view of the Milky Way.[36] Olympiodorus' commentary on Aristotle's *Meteorologica* contains additions to Aristotle's text, special interpretations, and points of criticism against Aristotle's opinions. For instance, Olympiodorus offered answers to certain questions concerning the halo and the rainbow that were beyond Aristotle's scope. Discussions of topics such as why the sea is salt, why wind moves horizontally, or whether the Milky Way is a phenomenon caused by the ignition of smoky exhalation in the upper atmosphere reflect different approaches adopted by Olympiodorus.[37]

### 3.2 *Physics*

Apart from the commentaries on Aristotle's *Meteorologica* in late antiquity, several other commentaries that dealt with Aristotle's treatises of natural philosophy *Physica*, *De generatione et corruptione*, and *De caelo* supplemented the inquiry into Aristotelian physics at that time. Specifically, Themistius (AD *c.* 317–*c.* 388), Simplicius (*c.* 490–*c.* 560), and John Philoponus wrote paraphrases or commentaries on Aristotle's *Physica* and contributed significantly to the transmission and creative reception of Aristotelian physics in later centuries.

Themistius' paraphrase of Aristotle's *Physica*, which relied heavily on a relevant—no longer extant—commentary composed by Alexander of Aphrodisias, offered innovative thoughts on Aristotle's physical concepts about principles, causation, change and infinity, dimensions of space, concepts of time as countable segments of movement, and the existence of the void.[38]

John Philoponus, whose belief in monophysite Christianity led him to argue against some of the physical theories of Aristotle, left a significant imprint on the reception of Aristotelian physics and its transmission into the Arab world and the Latin West.[39] Philoponus' exhaustive—though only partially extant—commentary on Aristotle's *Physica* examines in a critical and creative way issues arising from Aristotle's physics. Yet, in some topics, Philoponus came to radically different conclusions from Aristotle. His most important and influential ideas on physics included the identification of the natural place and the void, the suggestion of a driving force imparted to moving things by the mover as an alternative to the Aristotelian forced motion, his criticism of the Aristotelian theory of aether as the fifth element of which the heavenly

36 Lettinck, *ibidem*, pp. 42–44, and pp. 73–74 respectively.
37 *Ibidem*, pp. 256–57, pp. 130–33, p. 163, and p. 74 respectively.
38 Kupreeva, "Themistius," pp. 402–5.
39 Wolff, "Philoponus and the rise of preclassical dynamics," pp. 125–60.

bodies are made, and his criticism of Aristotle's arguments on the eternity of time and motion.[40] Moreover, Philoponus suggested original solutions to physical problems: he proposed that a projectile motion would gain momentum from the mechanism that fired it, thus arriving at a crude idea of inertia; he introduced a new approach in the usage of the notions of "motion" and "action" in their application to light and colour, and he supported the significance of the observer in the perception of time as a continuous and unbreakable flow.[41]

Simplicius is well known for his polemic against John Philoponus about the issue of the eternity of the world. Simplicius' commentary on Aristotle's *Physica*, written in an academic and didactic style, preserves valuable information from earlier Greek philosophers, as well as some critical points on physical problems. Specifically, in two lengthy digressions (corollaries) of the work, Simplicius offers his most original contribution in Aristotelian physics about time and place. On the one hand, Simplicius criticizes the static concept of the Aristotelian two-dimensional place, by drawing on Theophrastus. On the other hand, he responds to Aristotle's rejection of the paradoxes on whether time exists at all, and he adopts a Neoplatonic concept of time by stressing that time exists as something which continuously comes into being, divisible, as Damascius (458–550 CE) taught, in thought only. Furthermore, Simplicius adds his own solution by asserting that time is infinite, if viewed as a cycle.[42]

## 4 Meteorology and Physics in Christian-Patristic Theological Thought (4th–8th century CE)

In the theological thought of the Post-Nicene Patristic period (325–787 CE), inquiry into nature led to theology, and there was no operation within pure nature that could be abstracted from divine activity.[43] Thus, the fundamental theological interpretation of nature and the cosmos by the Christian fathers had implications for the way through which natural processes were theoretically approached. Concepts of physics, including meteorology, can be deduced

40 On topics of criticism by Philoponus against Aristotle, see the articles included in: Sorabji, *Philoponus and the Rejection of Aristotelian Science*, pp. 1–268.

41 Henry, "John Philoponus," pp. 642–46. For Philoponus' perception of time, see Kalachanis et al., "The Perception of Time by Humans according to John Philoponus," pp. 279–85.

42 For Neoplatonic approaches of Aristotelian physics, see Opsomer, "The integration of Aristotelian physics in a Neoplatonic context," pp. 189–229. For Simplicus' novelties on physics, see Baltussen, "Simplicius of Kilikia (530–538 CE)," pp. 743–45.

43 Hankey, "Natural Theology in the Patristic Period," pp. 38–56.

from general cosmological interpretations by the Orthodox Church fathers. We can identify two approaches concerning the explanation of meteorological phenomena. The one approach echoes the influence of Aristotelian meteorology, and owes its roots to the classical educational background of the Christian fathers. The second approach reflects the influence of Biblical representations of the cosmos and nature through a theological symbolism rooted in Babylonian or Jewish cosmology, which eventually contradicted the doctrines of natural philosophy.[44]

The two Cappadocian fathers Basil of Caesarea (*c.* 330–379) and Gregory of Nyssa (*c.* 330–*c.* 395) had a vast knowledge of ancient (Aristotelian and Stoic) natural science. This scientific knowledge also included meteorology, as it is evident from occasional references to meteorological topics in the theological texts of the Cappadocian fathers. Traces of meteorological knowledge of Aristotelian origin are detectable, even though the focus of the Christian fathers was far from the systematic explanation of the processes of nature, as was the case for Aristotle and later philosophers. Specifically, the Aristotelian notions of exhalation, evaporation, and condensation, as causes and mechanism for the formation of meteorological precipitation, are present in the theological treatises of Gregory of Nyssa, and Basil of Caesarea.[45] These two Church fathers had no reluctance in using meteorological knowledge derived from pagan philosophy to praise God and to insert reason into the theological context. For instance, Basil of Caesarea integrates references to the meteorological mechanism of cloud and rain echoing doctrines of Aristotelian origin in a metaphor that aims to convey moral messages.[46]

On the other hand, from a Christian perspective concepts of nature contradicted the doctrines of natural philosophy, which were considered as irrelevant for salvation from a theological point of view. Characteristic cases of Christian authors, who attacked Aristotelian features of natural philosophy

44 See Nicolaidis, *Science and Eastern Orthodoxy*, p. 24.

45 See Hoffmann, *Die Anschauungen der Kirchenväter über Meteorologie*, and Wallace-Hadrill, *The Greek patristic view of nature*, pp. 21–22.

46 Basil of Caesarea, *Enarratio in prophetam Isaiam*, 5.148.19–31 (transl. Lipatov, p. 171): "So, what are the clouds, and what is the shower? Let us try to understand the meaning of the passage from inquiry into the nature of clouds. Now a cloud is a dense air composed of an earth-like exhalation from the wet earth, which is then raised to a height by winds. When it receives from them a considerable concentration and acquires sufficient weight from the moisture dispersed in it, then it discharges drops to the earth. And this is the nature of showers which have their origin from the earth and through the air are brought again back upon the earth. Such were also the prophets, originating from common nature, but raised on high through the purity of their soul by the power of the Spirit and pouring the drops of their fertilizing words into good and fruit-bearing souls."

including meteorological theories, are Pseudo-Justin (5th century CE), Cosmas Indicopleustes (6th century CE), Pseudo-Kaisarios (6th century CE), John of Damascus (*c.* 675–749), and George of Pisidia (7th century CE). Pseudo-Justin attacked Aristotelian concepts in physics and cosmology by asserting that time, motion, and matter (both heavenly and terrestrial) are not eternal, and that there is, therefore, no eternal elemental component (aether).[47] Cosmas Indicopleustes introduced a religious cosmology in which the world's reality is based upon theological symbolism. In his *Topographia christiana* (Christian topography), Cosmas refutes the natural philosophy of the ancients and replaces it by the mechanics of angels, which is responsible for the manifestation of all natural processes. Earthquakes and precipitation are topics upon which Cosmas raises questions about their explanation by profane philosophers.[48] Pseudo-Kaisarios' *Πεύσεις* ('inquiries'), focuses on—among other things—cosmological and meteorological issues that must have arisen among Christians as the result of the silence of the Genesis on several aspects of the creation.[49] An analogous attempt to disparage the value of pagan philosophy in order to replace it with theology is evident in two different parts of John of Damascus' tripartite work *Πηγὴ γνώσεως* (Fountain of knowledge). Basic elements of Aristotelian doctrine on meteorology and physics are blended with popularized conceptions of nature and meteorological phenomena.[50] Similarly, George of Pisidia composed a Hexaemeron in verse that combined strong interests in natural science with the rejection of ancient ideas which could not be reconciled with the Christian dogma, including Aristotle's theory of the eternity of the world.[51] Within this framework, George of Pisidia sarcastically attacked Aristotle's meteorological explanation of the formation of hail.[52]

47 Boeri, "Pseudo-Justin on Aristotelian Cosmology," pp. 99–135.

48 Cosmas Indicopleustes, *Topographia Christiana*, ed. & transl. Wolska-Conus, 1.21–22, and 23–27; see Nicolaidis, *Science and Eastern Orthodoxy*, pp. 26–39.

49 Pseudo-Kaisarios, *Questions and answers*, ed. Riedinger: (55) When was air created?, (55) How was fire created?, (56) Why is there no thunder or lightning in winter?, (66) How is the firmament able to withstand the pressure of so much water?; see Papadogiannakis, "'Encyclopedism' in the Byzantine question-and-answer literature," pp. 33–34.

50 John of Damascus, *Capita philosophica* (Philosophical chapters), ed. Kotter, 68.1–68: A brief presentation of key notions of physics and meteorological phenomena, mostly of Aristotelian origin; John of Damascus, *De fide orthodoxa* (Orthodox faith), ed. Kotter: A detailed discussion of the nature of the heavens (20), of celestial and astral phenomena (21), of air and winds (22), of waters (23).

51 The term "Hexaemeron" denoted an account in Genesis 1 of the creation of the universe in six days. It also connotes the patristic commentaries on the topic as well as other writings on this narrative that form a distinctive literary genre in Byzantium, see also chapter 8 in this volume.

52 George of Pisidia, *Versus in Hexaemeron*, ed. & transl. Gonnelli, verses 553–96.

## 5 Weather Lore in Byzantium (4th–15th century CE)

Weather lore was a persistent presence in Byzantium, because of its association with the practical aspects of human life. Ancient Greek and Roman weather lore was based on observations of meteorological phenomena that were conceived as prodigies for human affairs, and from observations of natural processes that were perceived as signs of the manifestation of meteorological phenomena. Phenomena associated with the appearance of comets and shooting stars, thunder and lightning, or the manifestation of earthquakes, floods, etc., were attributed by the Byzantines to divine providence through signs (σημεῖα, θεοσημεῖα) and, thus, were recorded in various Byzantine texts as portents of impending catastrophes or of political and dynastic change (death of rulers, rebellions, military defeats, etc.). Characteristic texts of this type of prognostication were practical, mostly anonymous, manuals that offered divination on socio-political events obtained from observations of natural portents, such as earthquakes (*seismologia*), and thunder (*brontologia*).[53]

On the other hand, the existence of a wealthy Greek and Roman tradition of meteorological manuals of weather prediction, aided the transmission and further elaboration of a large circle of knowledge of weather prognosis in Byzantium. This knowledge was based on the signs (ἐπισημασίαι) that could be deduced from various astronomical, meteorological, biological or geographical observations and events.[54] The forecast of rain, winds, storm or fair weather could be made from the observation of stars (sun, moon, planets, shooting stars, etc.), of other meteorological phenomena (cloud formations, halos, thunder, lightning, winds, etc.), of the behaviour of birds, animals, insects, plants, or by observation of the mountains, etc. Contrary to theological objections raised against astrology in Byzantium, prognostication of forthcoming natural and weather events enjoyed acceptance by the Orthodox Church.[55]

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53 Dozens of Greek *brontologia* and *seismologia* have been published in the *Catalogus Codicum Astrologorum Graecorum*; see Trombley/Kazhdan, “Brontologion,” p. 326. On this literary genre, see also chapter 13 in this volume.

54 For a survey of the relevant texts in Greek and Roman antiquity, see Sider/Brunschön, *Theophrastus of Eresus. On weather signs*, pp. 11–27. On weather prognostication based on astral observations (astro-meteorology) in Greek and Roman antiquity, see Hübner, “L’astrométéorologie dans l’Antiquité classique,” pp. 75–94.

55 Basil of Caesarea, *Homiliae in Hexaemeron* (Homilies in the Hexaemeron), ed. Giet, 6.4 explains the usefulness of observing the heavens for signs of the weather, before he launches a lengthy attack on astrology. John of Damascus, *De fide orthodoxa*, ed. Kotter, 21.117–22 also refers: “The Greeks [i.e. the pagans] assert that human affairs are governed by the rise and setting of the stars, sun, and the moon; all these are the object of astrology. Conversely, we say that from all these we obtain signs (σημεῖα) of rain, drought, freezing,

As one can assume from the variety of texts and authors engaged with weather lore in Byzantium, weather prediction was a topic of considerable interest among the Byzantines appealing to different levels of interest. In early Byzantium, John Lydus' (490–*c.* 560) *De ostentiis* (On celestial signs) offered a collection of meteorological prodigies and portents including signs related to earthquakes, the phases of the moon, lunar and solar eclipses, the apparitions of comets, etc. The work stands as a link in a tradition of calendrical and meteorological astrology rooted in astro-meteorological concepts of the Roman and Etruscan religion. John Lydus adopted a conscious focus on ancient weather lore and emphasized the different needs served by weather prediction and scientific meteorological explanations.[56]

In the 10th century AD, the *Geoponica*, a farming manual dedicated to the emperor Constantine Porphyrogenitus, offered a collection of excerpts from ancient agricultural literature.[57] Its first book distils useful knowledge culled from various ancient sources (e.g. Aratos, Didymus, Zoroaster, Ptolemy, Sextus Julius Africanus, etc.) on meteorological prognostication that was important for farmers.[58] Furthermore, astro-meteorological prediction was part of practical knowledge, useful not only for farming, but also for seafaring and diplomacy. A pair of technical texts of the same period comprise, in all probability, the replies of local Byzantine naval commanders to a questionnaire sent out by Constantine Porphyrogenitus when he was preparing an authoritative treatise on naval and military meteorology, quoted in his *De cerimoniis aulae Byzantinae* (On the order of the palace).[59]

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heat, and moisture or dryness of the winds, but in no case signs of human deeds" [suggested translation].

56 John Lydus, *De ostentiis*, transl. Bandy, p. 59: "We are eager to speak about [the celestial phenomena], not so as to recount their natural causes or the speculations about them, for the particulars about these things clearly should be reserved for the philosophers, but to learn perhaps beforehand how it is possible naturally from these celestial signs the occurrence of future events."

57 On this work, see also chapters 8 and 11 in this volume.

58 *Geoponica*, ed. Beckh and transl. Dalby, 1.2–16. Chapters' titles: Signs of calm weather; signs of bad weather and how to foretell rain; signs of a long winter; predicting whether the spring will come early or late; forecasts from the first thunder after the rising of Sirius; the names of the winds, how many there are, and where they blow from; the twelve year cycle Jupiter, and what its presence in each of the twelve houses of the zodiac foretells; on sun and moon; on hail; on thunderbolts.

59 Constantine Porphyrogenitus refers to the necessary manuals that the emperor (Romanus I) should have with him and consult when in command of his army; Constantine Porphyrogenitus, *De Cerimoniis aulae Byzantinae*, ed. Reiske, p. 467,8–15: "a book concerning good and bad weather, storms, rain, thunder and lightning, changes in the wind, and also such things as the books of thunder (βροντολόγιον) and earthquakes (σεισμολόγιον) as

The text shows how important astro-meteorology was for the Byzantine court.[60]

Astrology and the subsequent astro-meteorological knowledge were topics very much appreciated in the learned circles of the 12th century Byzantine court. A characteristic example of this kind of astrological literature is John Camaterus' *Introductio in astronomiam* (Introduction to astronomy), an astrological verse tract compendium of earlier knowledge on the influence of the constellations on earthly life, including weather, which was dedicated to the emperor Manuel I Komnenos.[61]

## 6 Meteorology and Physics in the Byzantine Learned Circles of the 11th–12th Centuries AD

In the 11th century, the interest among Byzantine scholars in the physical world and its investigation through the intellectual achievements of ancient natural philosophy coincided with the rediscovery of the Aristotelian doctrines and the evaluation of the contribution of Greek Neoplatonist commentators (6th century CE) to their study.[62] Even though a gap in philosophical inquiry can be observed during the so-called "dark ages" of Byzantine history, it is beyond doubt that Aristotelian natural philosophy survived, as it is evident from the reproduction of the original Aristotelian physical treatises in manuscripts from the 9th century onwards.[63]

mariners are wont to observe. I, Constantine, Emperor of the Romans in Christ the Emperor Eternal, have labored lovingly on such a work which I have compiled from many sources" [suggested translation].

60 The texts are entitled: 1. "The seasons and stars observed by Mardaite master mariners as frequently making for foul weather and storms at sea, and (also those making for) fair weather and calms, the time to make successful expeditions," 2. "(A treatise) of the protospatharios admiral of the Kibyrrhaiotai concerning the stars for which sailors keep watch as making for storms and bad weather at sea"; for translation of the texts, see Dolley, "Meteorology in the Byzantine Navy," pp. 5–16.

61 John Camaterus, *Introductio in astronomiam*, ed. Weigl, verses 3162–3202, offers prognoses related to thunder, lightning, comets, earthquakes and winds: weather predictions from the observation of the moon's colour (verses 3162–78), from the rainbow, halo of the moon (verses 3179–3202). For further sources and discussions of astrology in the middle and late Byzantine period, see: Magdalino, "Occult Science and Imperial Power in Byzantine History," pp. 119–162; Tihon, "Astrological Promenade in Byzantium in the Early Palaiologan Period," pp. 265–90.

62 See Lackner, "Die aristotelische Meteorologie in Byzanz," p. 640.

63 The earliest manuscripts containing selections from Aristotle's treatises on natural philosophy including *Meteorologica* and *Physica* (Paris, Bibliothèque nationale de France,

The revival of the study of Aristotelian meteorology and physics, especially after the 11th century, indicates a new awareness in scientific subjects which had been hitherto neglected or, at least, had been subjected to the exclusive scrutiny of theological thought in earlier centuries. This new scientific awareness had a rather theoretical character since it borrowed explanatory tools from the Aristotelian philosophy of nature, which was regarded as the most appropriate and efficient tool for comprehending and analysing the physical world on a rational basis. Aristotle's natural philosophy offered a solid base for the posing of questions about the causes of various phenomena, their possible periodicity, their association with common features, and finally their explanation by recourse to theories. This revived scientific interest in the phenomena and mechanisms of the physical world was supported by an intensive study of the Aristotelian physical treatises which remained connected to the Christian faith. At that time the scientific investigation of nature was regarded by Byzantine philosophers as a step ascending towards knowledge of God.[64] On the other hand, Byzantium played a part in the academic and scholarly study of Aristotle's natural philosophy in the 11th–12th centuries. The main aim of Byzantine scholars was to enrich the teaching of the *Quadrivium* of sciences (astronomy, arithmetic, geometry and music), which was a curriculum oriented towards the Platonic classification of sciences and, thus, it disregarded empirical knowledge of the natural world.[65]

Meteorology and physics are reflected in a variety of texts produced by Byzantine scholars, who acquired high rank educational and ecclesiastical offices in the 11th–12th century. Michael Psellos (1018–after 1081), who gave courses on Plato and Aristotle as "consul of the philosophers" in the school of philosophy in the University of Constantinople, bishop Eustratios of Nicaea (*c.* 1100), who was member of the famous learned circle of Anna Komnene,[66] magistros Symeon Seth (*c.* 1050), or John Italos (1025–after 1082) and Theodore of Smyrna (*c.* 1050–after 1112), both successors of Psellos in the school of philosophy in Constantinople, were scholars who turned to the study of Aristotle's natural

Par. gr. 1853 and Vienna, Austrian National Library, Vindob. phil. gr. 100), date from the 9th and 10th century, a period sometimes designated as the First Byzantine Humanism; see Brockmann, "Scribal Annotation as Evidence of Learning in Manuscripts from the First Byzantine Humanism," pp. 11–33.

64 Kazhdan/Epstein, *Change in Byzantine culture*, pp. 148–58.

65 See also chapter 2 in this volume.

66 The tradition of the Aristotelian commentators of the 5th–6th century AD was revived in the 12th century under the guidance of the empress Anna Komnene, who seems to have commissioned several scholars to write commentaries on previously neglected works of Aristotle; see Browning, "An unpublished funeral oration on Anna Comnena," pp. 393–406.

philosophy and dealt with various topics in meteorology and physics. Their texts are primarily concise works with a strong educational character, organized in the form of questions (ἀπορίαι) and answers (λύσεις), a genre that draws on relevant treatises of the late antiquity.[67]

Michael Psellos discussed meteorological topics from an Aristotelian point of view in the chapters of his short encyclopaedia which dealt with theology and science, entitled *De omnifaria doctrina* (Διδασκαλία παντοδαπή), as well as in several *Opuscula logica, physica, allegorica et alia* (Shorter logical, physical, allegorical and other writings). For his meteorological chapters, Psellos draws material from Olympiodorus' commentary on Aristotle's *Meteorologica* and offers a concise exposition of the meteorological phenomena and their causes based on Aristotelian theories relating to the opposition of the primary qualities (hot and cold, dry and moist), and the doctrine of the action of the dual exhalation for explaining them; topics such as the causes of the rainbow or of earthquakes are also discussed.[68] Despite the Aristotelian structure of meteorological topics, there are cases where Psellos finds fault with Aristotelian doctrine.[69] Symeon Syth's *Conspectus rerum naturalium* (On the things of nature), Eustratios' of Nicaea treatise *Περὶ βροντῶν καὶ ἀστραπῶν* (On thunder and lightning), and the *Anonymi Miscellanea philosophica* (*Codex Baroccianus Graecus* 131)[70] bear concise meteorological passages such as those exposed by Psellos, based on Olympiodorus' commentary and John Lydus' *De ostentiis*. These texts share a common attitude amongst their authors towards the teaching of key-topics of Aristotelian natural philosophy, particularly meteorology, as a preparatory tool for clarifying Christian doctrine.[71] The influence of Aristote-

67 Papadogiannakis, "'Encyclopedism' in the Byzantine question-and-answer literature," p. 39.

68 Michael Psellos, *Omnifaria doctrina*, ed. Westerink, 123–25, 139–50, 164; Michael Psellos, *Philosophica minora* (vol. 1 *Opuscula logica, physica, allegorica et alia*), ed. Duffy/O'Meara, 19–24, 26–29.

69 For instance, Psellos argues that the Milky Way cannot be a sidereal phenomenon, as Aristotle asserts, referring for support to Ammonius' view as expressed in Olympiodorus' commentary: Michael Psellos, *Philosophica minora* (vol. 1 *Opuscula logica, physica, allegorica et alia*), ed. Duffy/O'Meara, 24 (p. 91,60–62); see Bydén, "'No prince of perfection,'" p. 170.

70 Symeon Seth, *Conspectus rerum naturalium*, ed. Delatte, 26–35; Eustratios of Nicaea, *On thunder and lightning*, ed. Caudano, pp. 626–33; *Anonymi Miscellanea philosophica* (*Codex Baroccianus Graecus 131*), ed. Pontikos, 22–24, 26–28. The meteorological chapters of the *Miscellanea* display affinities both to Psellos' *Omnifaria doctrina* and the *Opuscula logica, physica, allegorica et alia*. Therefore, the authorship of the *Miscellanea* has been attributed to Psellos; see Pontikos, *Ἀνωνύμου Φιλοσοφικὰ Σύμμεικτα*, pp. xxxiii–xl.

71 In a characteristic passage, Psellos subordinates Aristotelian explanation of earthquakes to Christian faith in the following way: Michael Psellos, *Omnifaria doctrina*, ed. Westerink,

lian meteorological theories during that period is also attested to by their incorporation into theological works, which deal with the doctrine of creation in the exegesis of the Hexaemeron and the Psalms. Nicetas Choniates' (*c.* 1155–1217), *Panoplia dogmatica* (Panoply of doctrine) is a striking example of theological text of that kind.[72]

Physics is also present in the above-mentioned scholarly texts, as well as in a few further works of the 11th–12th century. Occasionally, Aristotelian notions of physics are dealt with as necessary adaptations to the Christian faith. For instance, Psellos' physics in the *Omnifaria doctrina* focuses on "nature" as the proximate cause of change and rest in bodies, which is implanted in them by the ultimate cause, which is God.[73] Furthermore, discussions on selected topics of Aristotelian physics, such as the four elements, the heavens, place, and time are included in these texts with emphasis on the presentation of ancient philosophers' different views. In *Quaestiones quodlibetales* (Questions and answers), John Italos paid attention to Aristotle's *Physica*, and discussed some key philosophical problems related to Aristotelian natural philosophy, such as the eternity of the world.[74] Physical concepts explained by means of a series of views representative of ancient philosophers, including Aristotle, offered by Theodore of Smyrna in his *Epitome de natura et de principiis naturalibus* (Epitome of nature and natural principles according to the ancients).[75] In this introductory compendium, Theodore presents central topics of Aristotelian physics (matter, form, privation, motion, place, time), and discusses the standard Aristotelian doctrine concerning the four primary qualities (hot, cold, dry, moist), which, when coupled in different ways, originate provide the origin of the four elements that Aristotle divided into active and passive.[76] Byzantine interest in

164.2–5 "God causes the earthquake, just like all other occurrences, in accordance with the [Psalm] 'The earth shall tremble at the look of Him'; proximate cause (προσεχὲς αἴτιον) of it, is the wind emitted from the earth, when it happens to flow inwards instead of being given off outward" [suggested translation]. An analogous approach is observable in Eustratios of Nicaea, *Περὶ βροντῶν καὶ ἀστραπῶν*, ed. Caudano, l. 5–17, where the author emphasizes the orthodoxy of his endeavor in dealing with thunder and lightning, and establishes God as the first cause of all natural phenomena.

72 Nicetas Choniates, *Panoplia dogmatica* I. 20–29, *Patrologia Graeca* vol. 139, pp. 1115–18 (only in Latin translation). Choniates' account of cosmological and meteorological questions is heavily indebted to Psellos' *Omnifaria doctrina*; see Pontikos, *ibidem*, pp. li–lii, n. 40.

73 Michael Psellos, *Omnifaria doctrina*, ed. Westerink, 57; see Bydén, "Natural Philosophy, Byzantine," pp. 859–60.

74 John Italos, *Quaestiones quodlibetales*, ed. Joannou, 91–93.

75 Theodore of Smyrna, *Epitome de natura et de principiis naturalibus*, ed. Benakis, pp. 1–55.

76 For a comparative analysis of Theorore's *Epitome* and its relationship with works composed by his immediate predecessors (Psellos' *Opuscula logica, physica, allegorica et*

Aristotelian physics during that period is supplemented by Michael Psellos' commentary on Aristotle's *Physica*, a text with a strong pedagogical character that aimed at offering a concise introduction to the topics and the terminology of the Aristotelian treatise.[77]

## 7 Rediscovering Aristotelian Meteorology and Physics in the Late Byzantine Period (13th–mid-15th Centuries)

Despite the political and military pressure experienced in the Byzantine empire after the Fourth Crusade and the capture of Constantinople in 1204, a new impetus was given to the study of Aristotelian natural philosophy and science during the early Palaiologan period (1259–1360).[78] Furthermore, in the late Palaiologan period until the Fall of Constantinople in 1453, there was a tendency among Byzantine scholars to emphasize the disagreements that existed between Plato and Aristotle. Simultaneously, the development of natural philosophy at the hands of Western scholars left an imprint on the reception of Aristotelian doctrine.[79]

The extensive study of the Aristotelian philosophy during the 13th and 14th centuries is testified to in several manuscripts by the systematic reproduction not only of Aristotle's philosophical treatises, but also by their late antique

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*alia* and John Italos' *Quaestiones quodlibetales*), see Trizio, "Ancient Physics in the Mid-Byzantine Period," pp. 77–99.

77 The pedagogical character of the work is established in the introduction: Michael Psellos, *In Aristotelis physicorum libros commentarium*, ed. Benakis, p. 2,1–9: "The present book, which we start with the help of God, belongs to the part of natural philosophy, which is considered as theoretical contemplation, and it is rather the beginning of physical studies, because it investigates the natural principles. It was written by Aristotle and is entitled *Lesson on the Nature*, since all physical and other treatises of Aristotle derive from lectures. These works are deep in content, and they require, as the saying goes, 'swimmers in depth.' Equally, this one has the greatest merit of having been so named, for it is the most difficult. In fact, the study of principles is the most laborious task in all disciplines, therefore the same applies to the study of the natural reality" [suggested translation]. The authorship of Psellos' commentary on Aristotle's *Physica* has been disputed. It has been argued that this work should be attributed to the late-13th-century scholar George Pachymeres; see Golitsis, "Un commentaire perpétuel de Georges Pachymère," pp. 637–76.

78 For the historical and intellectual context of this revival, see Fryde, *The Early Palaeologan Renaissance*, pp. 71–102.

79 Bydén, "'No prince of perfection': Byzantine anti-Aristotelianism from the patristic period to Pletho," pp. 147–76.

commentaries.[80] The intense activity in the production of manuscripts that reproduced Aristotelian treatises and commentaries fostered a large group of Byzantine scholars, who were sufficiently competent in various branches of philosophy—including natural philosophy—to produce compendia and paraphrases of them. Aristotle's *Meteorologica* and *Physica* occupy a place of choice among the treatises of natural philosophy with which the Byzantine scholars of the Palaiologan period were involved. The tradition of Aristotelian studies in natural philosophy in the late Byzantine period was continued by scholars such as Nikephoros Blemmydes (1197–*c.* 1269), George Pachymeres (1242–*c.* 1310), Joseph the Philosopher (*c.* 1260/80–*c.* 1330), Nikephoros Choumnos (*c.* 1250–1327), Theodore Metochites (1270–1332), Nikephoros Gregoras (1293–1361), George Gemistos Plethon (*c.* 1360–1454), and George Scholarios (1454–1456). These scholars either paraphrased, or commented on Aristotle's *Meteorologica* and *Physica*. In some cases, they discussed topics in meteorology and physics aiming at criticizing Aristotle's doctrines. In any case, the philosophical activity of those scholars reflects the degree of dominance that Aristotelian knowledge of meteorology and physics enjoyed at that time as systems of explanation of natural reality.

Nikephoros Blemmydes was the author of an *Epitome*, an extensive compendium of Aristotelian philosophy in two books (the first dealing with logic and the second with physics), clearly written for educational purposes in higher education. The work offers a useful overview of what a young student was supposed to know about logic, physics, astronomy, and meteorology. The second book of that compendium, entitled *Epitome physica* (Εἰσαγωγικῆς ἐπιτομῆς βιβλίον β΄, Περί φυσικῆς ἀκροάσεως),[81] discusses in 32 chapters the main topics in natural philosophy with necessary adaptations to Christian cosmological principles. In chapters 1–10, Blemmydes attempts to elucidate the basic concepts of Aristotelian physics, using, notably, Simplicius. Chapter 11 expounds the theory of the four elements, mainly in accordance with Aristotle and John Philoponus. Chapters 12–23 contain a meteorological part, largely based on Aristotle's *Meteorologica* and Alexander of Aphrodisias' commentary on it.[82] Chapter 24 offers a refutation of the Aristotelian doctrine of the eternity of the heavens, based on Aristotle's *De caelo*, Simplicius' and Philoponus'

80 Some 150 extant Aristotelian manuscripts were copied during the Palaiologan period; see Fryde, *ibidem*, p. 7.

81 Nikephoros Blemmydes, *Epitome physica*, *Patrologia Graeca* vol. 142, pp. 1024–1320.

82 For the reception, interpretation, and transmission of Aristotelian doctrine of winds, as presented in Blemmydes, *Epitome of Physics* chapter 17, see Valente, "The Doctrine of Winds in Blemmydes: On the Reception of Aristotelian Meteorology in the Palaeologan Age," pp. 231–47.

commentaries. Chapters 25–31 deal with various cosmological questions derived from on Cleomedes.[83]

Aristotle's *Physica* and *Meteorologica* were among the treatises that George Pachymeres paraphrased and commented on in his *Philosophia*, a bulky collection of compendium-like commentaries of selected Aristotelian treatises in 12 books. In *Philosophia* book 2, commentary on Aristotle *Physica*, Pachymeres offers a condensed version of Aristotle's *Physica* by applying a complex explanatory strategy that attributes to natural philosophy a value in terms of the accomplishment of the Christian idea of perfection.[84] *Philosophia* book 5, a commentary on Aristotle's *Meteorologica*, transfers faithfully meteorological doctrine derived from the four books of Aristotle's text, and adopts in parallel, comments derived from Alexander of Aphrodisias, John Philoponus and Olympiodorus.[85] Both Pachymeres' and Blemmydes' writings were composed in the form of useful handbooks for the teaching of Aristotelian natural philosophy. Consequently, they became reference books for Palaiologan scholars at the end of the 13th century, as it is evident from their extensive use as the main sources for the composition of other epitomic works. For instance, parts of Blemmydes' and Pachymeres' texts were incorporated into Joseph the Philosopher's (also known as "Rhakendytes," *c.* 1260/80–*c.* 1330) *Βίβλος εὐσυνόπτων μαθημάτων* (Encyclopaedia).[86] For the section of this encyclopaedia devoted to natural philosophy (Προοίμιον τῶν φυσικῶν ἀρχῶν), Rhakendytes copied almost slavishly parts from Blemmydes' *Epitome of physica* and extended passages from George Pachymeres' *Philosophia* book 5, commentary on Aristotle's *Meteorologica*.[87]

Theodore Metochites composed paraphrases of Aristotle's writings on natural philosophy, including *Physica* and *Meteorologica*, which were designed to

83 For a detailed presentation of Blemmydes' theory of elements expressed in the *Epitome physica* (chapter 11), a discussion on the existence of void inside or outside the universe (chapter 31), and his argumentation against the Aristotelian conception of an eternal heavenly body (chapter 24), see Bydén, *Theodore Methochites' Stoicheiosis Astronomike*, pp. 112–19, pp. 163–69, and pp. 178–88 respectively.

84 George Pachymeres, *In Aristotelis physicorum commentarium* (*liber ii*), transl. (in Latin) Philipp Bech, pp. 73–99. For a discussion of Pachymeres' authorial strategy on the basis of the poetic epilogue of Pachymeres' commentary on Aristotle's *Physica*, see Golitsis, "A Byzantine philosopher's devoutness toward God," pp. 19–127.

85 George Pachymeres, *In Aristotelis meteorologicorum commentarium* (*liber v*), ed. Telelis.

86 For an overview of Joseph Rhakendydes' Encyclopaedia, see Gielen, "Ad maiorem Dei gloriam," pp. 259–76.

87 Lackner, "Die aristotelische Meteorologie in Byzanz," p. 641. For a detailed presentation of the meteorological material that Rhakendytes copied from Pachymeres' *Philosophia* book 5, see George Pachymeres, *ibidem*, ed. Telelis, pp. 102*-12*.

facilitate the understanding of Aristotle's doctrines by offering them in a comprehensive and explanatory manner. His paraphrase of Aristotle's *Meteorologica* offers a comprehensive overview of the four Aristotelian books, and integrates material from Alexander of Aphrodisias' commentary.[88] Aristotle's natural philosophy, particularly physics and meteorology, was a source of study also for Nikephoros Choumnos, the Byzantine scholar who engaged in a scientific polemic with his rival Theodore Metochites. Six among the nine *Opera philosophica* (Philosophical treatises) of Nikephoros Choumnos discuss topics in natural philosophy and cosmology, including meteorology and physics, which in some cases reflect a substantially different view of Aristotle's doctrine.[89]

A clear anti-Aristotelian attitude is expressed in Nikephoros Gregoras' dialogue *Florentios*, which conveys a strong attack on Aristotle's views including those of natural philosophy. Meteorology endures only a small share of this attack, expressed in Gregoras' objection to Aristotle's doctrine on the formation of rivers. Gregoras denied Aristotle's view that rivers were formed by water

88 The introductory lines of the text feature the late Byzantine scholar's approach to Aristotelian meteorology as a system of physical knowledge. Theodore Metochites, *In Aristotelis meteorologicorum paraphrasis*, transl. (in Latin) Hervet Gentian, p. 575: "In the books of *Meteorology*, Aristotle puts forward to examine in detail—as he always makes clear in the proem of the first of these books—those processes which take place directly under the first element; i.e. the heavenly body, and the place within the continuous space of the motion of the stars, such as the so-called milky way, the comets, and those observable phenomena resulting by inflammation and motion: shooting-stars, torches, firewinds, and those of similar nature. Furthermore [he examines in detail], the phenomena which are considered to have their common consistency to air and water: rainbow, snow, rain, hail, hoarfrost and those of similar nature. Then, he continues the discussion with phenomena observable on earth: those taking place in the northern and southern parts of it, and those occurring in the areas between them, and the form of them (there are differences concerning the consistency of the earth; other parts of it are porous and rare in texture, other are more dense), and the phenomena that follow the incidence of winds, earthquakes, and other similar occurrences, which—[Aristotle] says—occur irregularly compared to phenomena occurring within the first celestial motion" [suggested translation]. For Metochites' dependence on Alexander of Aphrodisias' commentary, see Lackner, "Die aristotelische Meteorologie in Byzanz," p. 641.

89 For Choumnos' views on the nature of the physical world, on the primary and simple bodies, and for his controversy with Theodore Metochites on the nature of the heavens, see Bydén, *Theodore Methochites' Stoicheiosis Astronomike*, pp. 119–32, pp. 132–36, and pp. 171–95 respectively. Topics of meteorological importance are discussed in Choumnos' treatise entitled: "Περὶ τοῦ ἀέρος, τίνι λόγῳ καὶ αἰτίᾳ, θερμὸς ὢν τὴν φύσιν, ψυχρὸς ῥιπιζόμενος γίνεται· καὶ περὶ γενέσεως χαλάζης· καὶ περὶ φύσεως ἀνέμων καὶ τῆς δόξης τούτων φορᾶς καὶ κινήσεως" (On the air, why, in spite of its being by nature warm, it gets cold when blowing; further, on the generation of hail, and on the nature of the winds and their oblique blowing and movement); see Nikephoros Choumnos, *Opera philosophica*, ed. Chrestou, 8.

coming from the clouds, because he alleged that it contradicted a Platonic statement that rivers flow out of the centre of the earth.[90] On the other hand, the final phase of Byzantine philosophy is marked by the onset of a controversy over the primacy of Plato or Aristotle. The contrast which George Gemistos Pletho draws between Plato's and Aristotle's doctrine concerns not only metaphysics, but also physics. The tendency to exalt Plato and Neoplatonism at Aristotle's expense is obvious in Pletho's treatise *De differentiis* (On the differences between Plato and Aristotle), in which Pletho also exposes Aristotle's departures from Plato's views concerning topics related to physics.[91] In defence of Aristotle against Pletho's anti-Aristotelian criticisms, George Scholarios (Gennadios II) set out to highlight the work of Aristotle and to integrate scholastic philosophy within the Byzantine philosophical tradition. Physics and meteorology became part of Scholarios' endeavour to achieve this by summarizing Aristotle's *Physica* and *Meteorologica*.[92] Moreover, Scholarios translated, summarized, and commented on Thomas Aquinas' commentaries on Aristotle's *Physica*.

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Meteorology and physics in Byzantium were disciplines interrelated within the system of Aristotle's natural philosophy. Aristotle's *Meteorologica* and *Physica* offered a well-organized scientific basis for the interpretation of natural mechanisms, and the explanation of atmospherical and terrestrial phenomena that nowadays are explored within the earth sciences. Meteorology in Byzantium involved not only the theoretical approaches included in philosophical and theological texts, but also offered practical forecasts included in weather lore and other accounts that did not conform to scientific and religious explanations. Physics in Byzantium was chiefly a topic of philosophical inquiry, rather than a field of experimental research in the modern sense of the term.

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90 Nikephoros Gregoras, *Florentius sive De sapientia*, ed. Leone, lines 1252–1320; see Fryde, *The Early Palaeologan Renaissance*, p. 367.

91 Discussion of the fifth element, questions on physics including Aristotle's conception of teleology, and the concept of motion: George Gemistos Pletho, *De differentiis*, ed. Lagarde, chapters 14, 15–27, 19 respectively; see Karamanolis, "Plethon and Scholarios on Aristotle," pp. 253–82.

92 George Scholarios, *Adnotationes in Aristotelis opera diversa, Ph. 1–8*, ed. Jugie/Petit/Siderides, v. 7, pp. 349–408; *Mete. 1–4*, *ibidem*, pp. 470–81.

CHAPTER 6

# Astronomy and Astrology

*Anne-Laurence Caudano*

In 1960, Otto Neugebauer aptly remarked about Byzantine mathematical astronomy that "[p]eripheral subjects have been treated more often."[1] Indeed, Byzantine astronomy and astrology are rarely discussed meaningfully in syntheses of the history of science or astronomy.[2] The Byzantines' role in preserving ancient astronomy is often emphasized, but unfortunately, their astronomical tradition is brushed aside. Important studies on the subject have appeared, however, and an increasing number are being published.

Neugebauer's own *History of Ancient Mathematical Astronomy* referred to Byzantine material when the opportunity arose, and his successor at Brown University, David Pingree, delved into much Byzantine astrological material and the intricate patterns of transmission between Byzantium and the East. Byzantine astronomical and astrological texts, however, have kept editors occupied for a long time. Stephen of Alexandria's *Commentarium in Ptolemai canones* (*Commentary to Ptolemy's Handy Tables*) was published partially by H. Usener in 1880.[3] The *Catalogus Codicum Astrologicum Graecorum*, a collection of catalogues of astrological manuscripts published between 1898 and 1953, offered, beside manuscript descriptions, full or partial editions of astrological and astronomical texts. It remains to this day an invaluable resource.[4] Editions of many works of Late antique and Byzantine astronomy were published by the Université Catholique de Louvain (Belgium), under the leadership of Canon Adolphe Rome and his student Joseph Mogenet,[5] who, in 1962, was also the first to identify Byzantine astronomical approaches in scholia to an Arabic astronomical text.[6] Anne Tihon followed in Mogenet's footsteps and devoted her career to the edition, translation, and analysis of a number of

1 Neugebauer, "Studies in Byzantine Astronomical Terminology," p. 3.

2 See for instance, D. Lindberg, who devoted only four pages to Byzantine sciences in his otherwise excellent survey of medieval sciences (Lindberg, *The Beginnings of Western Science*, pp. 159–62). It is hardly mentioned in the *Cambridge Illustrated History of Astronomy* edited by M. Hoskin.

3 Stephen of Alexandria, *Commentarium in Ptolemai canones*, ed. Usener.

4 *Catalogus Codicum Astrologorum Graecorum*, 20 vols., Brussels 1898–1953.

5 Their publications notably include editions of the works of Pappus and Theon of Alexandria.

6 Mogenet, "Une scolie inédite."

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important Late antique and Byzantine astronomical works. She also encouraged her own students to edit and analyze Byzantine texts as part of their undergraduate or doctoral theses.[7] These textual approaches, albeit very necessary, may have unwittingly contributed to considering Byzantine astronomy as a philological field rather than an inherent part of the history of science. This is currently changing, however, as more studies are being produced, for instance on the place of the sciences in the Orthodox world or on the role of Byzantine scholars in the astronomical discussions and scholarly networks of the Renaissance.[8]

Interest in astronomy and astrology is manifest throughout Byzantine history.[9] The level achieved at various times or by various scholars differed, however, ranging from elaborate calculations, such as astrological *thematia* and eclipse predictions, to a basic understanding of the movements of celestial bodies. Principally the heirs of the Ptolemaic tradition, Byzantine astronomers sought to provide the tools and tables that allowed for the continuous use of the works of Ptolemy (fl. *c.* 130–175) or his commentators, although Byzantine adaptations of Arabic, Latin, and Jewish works also circulated, particularly in the Palaiologan period (1261–1453).

Just as many of their medieval counterparts, Byzantine astronomers were generally conversant in other fields; astronomy was rarely their only activity. For instance, Stephen of Alexandria (fl. early 7th century), the author of the first treatise of astronomy adapted to the coordinates of Constantinople, was probably also behind commentaries on Aristotle, Porphyry, or Galen. Nikephoros Gregoras (d. *c.* 1360), the author of several eclipse calculations, is generally better known for his *Roman History* and also penned hagiographic and

7 Unfortunately, these undergraduate theses are only held at the library of the University of Louvain-la-Neuve and are difficult to access. A. Tihon is also the editor of the Corpus des Astronomes Byzantins, a series devoted to the publication of Byzantine astronomical texts. Some of her doctoral students include R. Leurquin, who published the first two volumes of Theodore Meliteniotes' *De astronomia libri III* (*Three Books on Astronomy*) and J. Lempire who has edited the first sixteen chapters of Stephen of Alexandria's commentary.

8 An important study on the relationship between Byzantine Orthodoxy and astrology was published by P. Magdalino in 2006 (*L'orthodoxie des astrologues*). More than half of E. Nicolaidis' *Science and Eastern Orthodoxy* (2011) is devoted to the Byzantine period with much discussion of astronomy. The relationship between science and the Orthodox world was also recently featured in a special issue of the journal *Isis* (Cohen [ed.], "Viewpoint: Science and Orthodox Christianity"). For discussions on the role of Byzantine astronomers in Latin, Jewish, Persian and Ottoman scholarly networks in the Eastern Mediterranean and Europe more generally, see the recent work of A. Tihon, J. Ragep and R. Morrison (Tihon, "De même qu'on peut voir les abeilles"; Tihon, "Astronomie juive"; Ragep, "From Tūn to Toruń"; Morrison, "Jews as Scientific Intermediaries").

9 On astrology, see also chapter 13 of this volume.

rhetorical works. George Gemistos Plethon (*c.* 1360–1452), to whom is attributed the most creative Byzantine astronomical tables, is more usually cited for his stringent Neoplatonism and his remarkable views of society.

Along with such wide-ranging interests, the priorities of these Byzantine scholars also varied. In this chapter, emphasis is set on the heavens as they were understood and transposed in mathematical terms, through geometrical models and arithmetical procedures. Yet, these same heavens were also discussed by philosophers in terms of essence, substance, or cause (i.e. physics). Byzantine authors sometimes chose to emphasize the former or the latter approach, depending on how they understood their relative importance: the mathematical predictability of celestial movements, or their essence and substance. This distinction even led, in the 14th century, to passionate debates about the significance of astronomy with respect to physics.[10]

Furthermore, while the Byzantine view of the universe was predominantly Ptolemaic (i.e. spherical), manuscripts show that other ideas also circulated among the literati.[11] These alternative conceptual worldviews were sometimes influenced by religious concerns, as in the box-like universe inspired by the Bible, or stemmed from older sources more difficult to identify, but still copied until the end of the Byzantine empire.[12] While these texts are important for our understanding of the relations between science and religion in Byzantium,[13] or for the study of Byzantine "popular science," they rarely entail astronomical discussions *stricto sensu* and, as such, will not be discussed extensively here.

Finally, following Ptolemy's distinction, most Byzantine scholars distinguished clearly between the theoretical study of the stars and their movement (astronomy), and their influence on the physical world (astrology). The two disciplines were intricately linked, however, since astrologers needed astronomical tables to cast horoscopes.[14] Discussions regarding the boundaries of astronomy and astrology, and the legitimacy of some aspects of the astrologers' endeavours, but not all, appear in letters and even in the *Quadrivium* where basic definitions relevant to astrology are usually found. The distinction between the two disciplines was not obvious to all, however, a fact which, in

10 Manolova, *Discourses of Science*, pp. 115–21.
11 See also chapter 5 of this volume.
12 Caudano, "Cosmologies et cosmographies."
13 On this particular issue, see Nicolaidis, *Science and Eastern Orthodoxy*, pp. 1–129.
14 This is why important information on astronomical tables appears in astrological texts (Tihon, "Les sciences exactes," p. 421).

the 12th century, led some to call for a ban on the study of astronomy altogether, although this extreme position was hardly observed.[15]

## 1 The Sources of Byzantine Astronomy and Astrology

In the early days of the Byzantine empire, Alexandria was the most prominent centre of scientific learning, although other schools existed elsewhere, notably in Syria and in Athens.[16] Much of Byzantine mathematical astronomy is indeed grounded in the works of the Alexandrian astronomer Ptolemy (fl. 146–*c.* 170 CE) and those of his later commentators, such as Pappus (fl. *c.* 320), Theon (fl. *c.* 360–380), and Proclus (d. Athens 485) among others. Ptolemy's most important works for the Byzantine astronomical tradition were the *Syntaxis mathematica* (*Mathematical Syntaxis*) and the *Πρόχειροι κανόνες* (*Handy Tables*). The first, better known as the *Almagest*, is a systematic compilation of Greek mathematical astronomy in 13 books, which offers the theories, models, methods, and tables necessary for the calculation of the position of stars and planets. On Ptolemy's own admission, the text was aimed at readers with an elementary knowledge of geometry and arithmetic.[17] The *Handy Tables* compiled all the tables necessary for astronomical computations otherwise dispersed throughout the *Almagest*. The analysis of these tables reveals that a number of procedures required to use them had been simplified. Tables were also presented differently and updated the *Almagest* with improved parameters.[18] By the 4th century, Ptolemy's authority had been so firmly established that alternative astronomical compilations and tables were no longer copied, let alone produced.[19]

The *Almagest* itself had been adopted into the curriculum and was rarely criticized. Rather, the material was considered complex enough to warrant

15 About the place of astrology and its legitimacy in Byzantine Orthodox society, see Magdalino, *L'orthodoxie des astrologues*, which offers relevant information regarding the context for the practice of astrology and astronomy alike.

16 Tihon, "Les sciences exactes," p. 393.

17 Toomer, *Ptolemy's Almagest*, pp. 5–6. Ptolemy, *Syntaxis mathematica*, ed. Heiberg.

18 The tables of mean motions are also given by minutes rather than with six sexagesimals digits (Neugebauer, *A History*, pp. 969–75) A critical edition of the *Handy Tables* is currently under way. Only the tables of right and oblique ascensions have been edited in Ptolemy, *Πρόχειροι κανόνες*, ed. Tihon/Mercier.

19 Fragmentary evidence points to their existence around Ptolemy's time, however. See, for instance, the recently discovered papyrus Fouad Inv. 267A (Tihon, "Alexandrian Astronomy," pp. 85–88); and Artemidorus's criticism in a fragment dated *c.* 213 (Jones, "Ptolemy's First Commentator," pp. 10–12).

extensive commentaries by Alexandrian teachers. Essentially, these commentaries were aimed at teaching the skills necessary for calculations, rather than the rationale behind Ptolemy's comprehensive astronomical system. In this sense, they did not provide the students with tools to develop, improve, or even correct the parameters of Ptolemy's tables or his models.[20] Pappus's *scholia* to the *Almagest*, written *c.* 320, are a good example of this approach that essentially favoured such computational skills. His occasional mistakes and, sometimes, deliberate adjustments also show that by this time the level achieved by students had already dropped.[21] This is made clear by Theon who, in his commentary to the *Almagest*, felt the need to clarify some arithmetical methods and geometrical models, which Ptolemy had assumed from his readers.[22] Theon is also the author of two commentaries on the *Handy Tables*. The five books of the *Great Commentary to the* Handy Tables *of Ptolemy* (*Ὑπόμνημα εἰς τοὺς προχείρους Πτολεμαίου κανόνας* [*commentarium magnum*]) offered detailed explanations regarding the use of Ptolemy's tables, the reasons behind procedures, parameters, as well as geometrical proofs. The *Small Commentary to the* Handy Tables *of Ptolemy* (*Εἰς τοὺς προχείρους Πτολεμαίου κανόνας* [*commentarium parvum*]), in contrast, was a short version in one volume that Theon wrote afterwards for his students and that is restricted to mathematical procedures without their justifications.[23] Anonymous scholia were later attached to Theon's and Ptolemy's texts. Together, these works formed the most important pillars of astronomical studies in the Byzantine empire up to the 15th century.[24]

In Athens, the Neoplatonist philosopher Proclus offered an important synthesis of Ptolemaic astronomy, the *Hypotyposis astronomicarum positionum* (*Sketch of the Astronomical Models*), where he also criticized the complexity of Ptolemy's model of epicycles and eccentric spheres. As a philosopher, Proclus was more preoccupied by the cause of planetary motions than by their apparent movement. Thus, according to him, while the models of the *Almagest* offered the necessary mathematical tools to calculate the position of the celestial bodies, they were ultimately not grounded in the reality of their movement. In

20 Pingree, "The Teaching of the *Almagest*," p. 77.

21 Pappus altered some of his results to match the *Almagest* (Pingree, "The Teaching of the *Almagest*," p. 76). Only two complete books survive as well as fragments from other books (Pappus, *Commentaria in Ptolemaei syntaxin mathematicam 5–6*, ed. Rome).

22 Pingree, "The Teaching of the *Almagest*," p. 77. Only books I–IV have a modern edition (Theon, *Commentaria in Ptolemaei syntaxin mathematicam* (= *Almagest*), ed. Rome).

23 Tihon, "Alexandrian Astronomy," p. 90; Toomer, "Theon of Alexandria," p. 322. Theon, *Ὑπόμνημα εἰς τοὺς προχείρους Πτολεμαίου κανόνας* (*commentarium magnum*), ed. Mogenet/Tihon; Theon, *Εἰς τοὺς προχείρους Πτολεμαίου κανόνας* (*commentarium parvum*), ed. Tihon.

24 Tihon, "Les sciences exactes," pp. 392–93. About these scholia, see Pingree, "The Teaching of the *Almagest*," pp. 80–95.

spite of this reluctance, though, the *Hypotyposis* not only demonstrated Proclus's proficiency in Ptolemaic astronomy but also that Ptolemy's authority had been well established in the field. In the *Hypotyposis*, Proclus even described a variety of instruments, one of which was related to a graphic method for calculating the longitude of the sun alluded to in the *Handy Tables*, but not reproduced in Theon's version.[25]

Finally, Byzantine manuscripts have preserved the names, lecture notes, scholia, and observations of other scholars who worked in Alexandria (e.g. Hypatia, Synesios, or Serapion) and Athens (e.g. Marinos), though often fragmentarily.[26] Observations still took place, such as those made in Alexandria by Heliodoros and Ammonios between 498–510.[27] Ammonios's student, John Philoponos, was himself the author of *De usu astrolabii* (*On the Use of the Astrolabe*, *c.* 550), the oldest preserved treatise on the use of this instrument.[28]

Late antique astrology, like astronomy, relied on a material established by the 2nd century CE. These comprehensive textbooks included Dorotheos of Sido's astrological poems (*Pentateuch*, *c.* 75 CE), Vettius Valens's *Anthologiarum libri ix* (*Nine Books of Anthologies*, *c.* 152–162 CE), as well as Ptolemy's *Apotelesmatica* (four *Books of Effects*, better known as *Tetrabiblos*), the decisive statement of the scientific theory on the subject.[29] This material was then synthesized or compiled by a variety of authors, such as Paul of Alexandria (fl. 378), Hephaistion of Thebes (*c.* 415), or Rhetorios (*c.* 620).[30] Paul of Alexandria's *Elementa apotelesmatica* (*Introduction to Astrology*) notably served as a textbook of astrology, as is attested by its use in May-June of 564 during lectures that Olympiodoros delivered in Alexandria; the text was still studied in

25 Tihon, "Alexandrian Astronomy," pp. 74–76; Pingree, "The Teaching of the *Almagest*," p. 79; Proclus, *Hypotyposis*, ed. Manitius.

26 Lempire, "Le manuel d'astronomie," pp. 3–4. On the role of Syria in the transmission of the *Almagest*, see Pingree, "The Teaching of the *Almagest*," pp. 88–95.

27 Edition J.L. Heiberg, *Opera astronomica minora*, Leipzig 1907, pp. xxv–xxvii.

28 Philoponos discussed neither its construction nor the precession of the equinoxes. This suggests that he had at his disposal an instrument made relative to the longitude of the stars in the 6th century (Jarry, "Sur une recension du *Traité de l'astrolabe*," pp. 38–39; see also Tannery, "Notes critiques"). Two editions of this text have recently come out (John Philoponos, *De usu astrolabii*, ed. Jarry and ed. Stückelberger).

29 Magdalino, "The Byzantine Reception," p. 38; Pingree, "Classical and Byzantine Astrology," pp. 229–33. Dorotheos of Sido, *Carmen*, ed. Pingree; Vettius Valens, *Anthologiarum libri ix*, ed. Pingree; Ptolemy, *Apotelesmatica*, ed. Hübner.

30 Paul of Alexandria, *Elementa apotelesmatica*, ed. Boer; Hephaistion, *Apotelesmatica*, ed. Pingree; Rhetorios, *Compendium astrologicum*, ed. Pingree/Heilen; English transl. J. H. Holden.

the 9th and 12th centuries.[31] Rhetorios's compilation included a rich ensemble of classical and early Byzantine material, among them several horoscopes dated between 401 and 516.[32] His work only survived in Byzantine epitomes dated from the 10th or 11th centuries. These epitomes reproduce intermediate revisions from the 8th and 9th centuries, and were still copied in the Palaiologan period, which all attest to the continuous interest in this work.[33]

The rule of Justinian (r. 527–565), otherwise flourishing in literary and architectural productions, was not particularly fruitful in the fields of astronomy and astrology. This is likely the result of Justinian's laws against astrologers (or "mathematicians"), which forbade the interpretation of astronomy and seem to have affected Athens and Constantinople more than Alexandria. These decrees—so the story goes—led to the temporary exile of philosophers to Persia and the closing of the Academy of Athens, though the evidence about the sequence of these events is unclear.[34] John Lydos's work on omens is a notable exception, as it includes a number of prognoses based on meteorological and celestial phenomena.[35] Excerpts from his book were reproduced in later Byzantine compilations such as John Kamateros's 12th-century astrological poem.[36]

The Persian onslaught on Egypt, rapidly followed by the Arab conquest of North Africa in the first half of the 7th century, shifted scholarly production to Constantinople and the East. Stephen of Alexandria exemplifies this change, although much debate surrounds the identification of this scholar and the works attributed to his name, which may include commentaries on Aristotle, Porphyry, Hippocrates, and Galen, and alchemical works.[37] This discussion is beyond the scope of this chapter, but at the very least, he should not be

31 Olympiodoros is the likely author of the commentaries to Paul's *Introduction*, which manuscripts ascribe to Heliodoros (Olympiodoros, *Commentarium in Paulum Alexandrinum*, ed. Boer). On this attribution and the place of astrology in the Neoplatonic curriculum, see Westerink, "Ein astrologisches Kolleg," pp. 6–21.

32 Neugebauer/van Hoesen, *Greek Horoscopes*, pp. 132–35, 138–42, 146, 150–52, 157–58.

33 Pingree, "From Alexandria to Baghdad," pp. 6–13.

34 Magdalino, *L'orthodoxie des astrologues*, p. 27; Watts, "Where to Live the Philosophical Life."

35 John Lydos, *Liber de ostensis*, ed. Wachsmut.

36 Caudano, "An Astrological Handbook," pp. 58–59.

37 The most extensive attempt to reconstruct his life is Wolska-Conus, "Stéphanos d'Athènes et Stéphanos d'Alexandrie." The authorship of some philosophical works traditionally attributed to him has been recently questioned (Roueché, "Stephanus the Philosopher and Ps. Elias"). On Stephen of Alexandria's authorship of alchemical works, see Papathanassiou, *Stephanos von Alexandreia*, pp. 56–60.

confused with Stephen the Astrologer who lived a century later and to whom a horoscope of the birth of Islam has been attributed.[38]

Around 617–619, Stephen of Alexandria wrote a commentary on the *Handy Tables*, the first known astronomical treatise produced in Constantinople. This teaching manual is as practical in its objectives as its Alexandrian predecessors, particularly Theon's *Small Commentary*, from which it took its inspiration. Stephen's treatise discusses the procedures in calculating the positions of the planets, syzygies, and eclipses with the *Handy Tables*. Examples date from 617–619 and are adjusted to the coordinates of Constantinople.[39] The text also includes scholia and, at the end, a section on chronology introduced by Emperor Herakleios (r. 610–641), which prompted some Byzantine copyists to attribute the whole work to the Emperor himself.[40] Finally, Stephen's commentary ends with a discussion of the Paschal computus, which was added afterwards. Questions of chronology, such as the establishment of the Byzantine era counted from the Creation of the World (5508/9 BCE) or the calculation of the date of Easter, led to important discussions at the time, as attested by the treatises written by Maximos the Confessor, George the Monk and Priest, and the anonymous *Chronicon Paschale*.[41] These works also suggest that basic notions of astronomy were taught in ecclesiastical milieus.

According to his autobiography, the Armenian scholar Anania Shirakatsi (7th century) intended originally to perfect his mathematical education in Constantinople, though he ultimately opted for a teacher in Trebizond, Tychikos, who had been trained in Alexandria and Constantinople.[42] Upon his return to Armenia (*c.* 628), Anania taught the *Quadrivium* and composed works on geography, chronology, mathematics, and astronomy.[43] His *Cosmography*, written in Armenian, notably reproduces cosmological issues taught in

38 *Cf. infra*, pp. 211-12.; Lempire, "D'Alexandrie à Constantinople," pp. 261–62.

39 Stephen often used the era of Constantine, rather than Philip as did Ptolemy (324 BCE) or Diocletian as did Theon (284 CE). The date of the era of Constantine fluctuates between 628 and 632 of the era of Philip in the manuscripts, however (Lempire, "Le Manuel d'Astronomie," pp. 6–7). The first sixteen chapters have been edited, translated, and analyzed by J. Lempire (Stephen of Alexandria, *Commentarium in Ptolemai canones*, ed. Lempire). Until the rest of the work is published, readers may still refer to Usener's 1880 partial edition.

40 Lempire, "D'Alexandrie à Constantinople," pp. 244–48.

41 Lempire, "Le calcul de la date de Pâques." On Byzantine chronology in general, see Grumel, *La chronologie*.

42 Wolska-Conus, "Stéphanos d'Athènes et Stéphanos d'Alexandrie," pp. 20–24. Her identification of Tychikos's master as Stephen of Alexandria is plausible. On this issue, see also Papathanassiou, *Stephanos von Alexandreia*, pp. 54–55.

43 Hewsen, "Science in Seventh-Century Armenia," pp. 34–36.

the 7th-century Byzantine curriculum, issues that are reflected in anonymous works found in late Byzantine manuscripts.[44]

Little was achieved after Herakleios's reign in the field of astronomy before the 10th century. In northern Syria in the 6th and 7th centuries, the monastery of Qennešre produced Syriac translations but also commentaries on important Alexandrian scientific texts, which reflect the work done in the East around the time when these regions were conquered by the Arabs.[45] A compendium of Ptolemaic astronomy was notably produced in the 6th century, of which only the theory of eclipses has been preserved. The most prolific Syriac astronomer of the period was by far Severus Sebokht (d. 666/7). He was the author of a treatise on the astrolabe, allegedly based on Theon's work on the subject, and of several other texts that discuss astronomical questions and the calendar.[46] Most curious, in one of Sebokht's works is his retelling of a Chaldean legend that ascribed eclipses to the intervention of a dragon. Sebokht dismissed this explanation as fable, but traces of this belief seeped back in later Byzantine manuscripts up to the 15th century.[47] While Anania and Sebokht wrote respectively in Armenian and Syriac, their work remains helpful when studying Byzantine manuscripts, which sometimes reproduce anonymous sources whose origins and transmission are often obscure.

## 2 Astronomy and Astrology in the Iconoclastic and Macedonian Periods

Only traces of elementary teaching remain from the 8th–10th centuries, though astronomical works were also copied. Basic astronomical knowledge appears for instance in chapters 20 (*on Heaven*) and 21 (*on Light, Fire, Luminaries, Sun, Moon, and Stars*) of John Damascene's *Expositio fidei* (*Exact Exposition on the Orthodox Faith*, *c.* 743), the third part of a larger synthesis of philosophy and theology.[48] Simple explanations of astronomical phenomena are offered on days and nights, seasons, eclipses, lunar phases, or even dates when the sun enters each Zodiacal sign. While most of these definitions are correct, the text is not always clear, as the bishop of Damascus explained several theories regarding the heavens, but did not privilege any one of them. For instance, the vaulted box-like heaven of the Bible is discussed next to the spherical world of

44 Caudano, "Cosmography, Asceticism and Female Patronage," pp. 32–33.
45 Dubié, "Sciences et savants syriaques," pp. 37–39.
46 Villey, "Qennešre et l'astronomie," pp. 160–81.
47 Baudry, "Un traité cosmologique byzantin inédit," pp. 16–18.
48 John Damascene, *Expositio fidei*, ed. Kotter, pp. 50–62.

Aristotle; several hypotheses regarding the number of the heavens or the relative sizes of the earth and the sun are also found indiscriminately next to one another.[49] Finally, the dates attached to the sun's movement throughout the Zodiac do not conform to an 8th-century situation.[50] We are far from the achievements of Alexandrian astronomy, but the importance of this text should not be downplayed either. Indeed, for many Orthodox readers—Byzantine and Slavic—this was one of the most accessible introductions to the subject.[51]

Astrology was practiced, however, as an art for which astronomical tables must be used. The harvest is more bountiful in this field, but originates beyond the boundaries of the empire. Theophilos of Edessa, a Syrian Maronite Christian, who worked as a military advisor to Caliph al-Mahdi between 775 and 785, is better known for his translations of Homeric poems into Syriac, but he was also the author of four astrological works written in Greek. Theses treatises combined Hellenistic astrology with Persian and Indian sources, and returned to Constantinople possibly thanks to one of his students, Stephen the Astrologer, a character well attested in Greek and Persian sources but often confused with Stephen of Alexandria, who lived a century earlier.[52] Stephen the Astrologer himself started his career in Baghdad, but moved to Byzantium *c.* 775.[53] His name is associated with three texts: a treatise of political astrology on the conjunction of Saturn and Jupiter, an apology for astrology, and *De arte mathematica* (*On the art of Mathematics*). Stephen's brief defence of astrology as a Christian science also served as an introduction to a horoscope of Islam, which offers a range of predictions from the rise of Islam to its alleged fall.[54] The *themation* is dated to 621 but was more likely elaborated *c.* 775–780, since the prognoses only prove correct up to that time.[55] In the third text, *On the art*

49 John Damascene, *Expositio fidei*, ed. *ibidem*, pp. 52–53, 60.

50 Tihon, "L'astronomie à Byzance à l'époque iconoclaste," p. 183.

51 Caudano, "Le ciel," pp. 45–46. These chapters circulated sometimes independently in Byzantine manuscripts (e.g. in Paris, Bibliothèque Nationale, Paris. gr. 854, fols. 20r–22v and 197v–200r, and in London, British Library, Harleianus 5624, fols. 273r–282v), as well as in the Slavic world where it sometimes bore the title "Book of the Heavens" (Sadnik, *Des Heilige Johannes von Damaskus*, p. viii).

52 Dubié, "Sciences et savants syriaques," pp. 52–53; Pingree, "Classical and Byzantine Astrology," pp. 236–38; Tihon, "L'astronomie à Byzance à l'époque iconoclaste," pp. 190–92. Regarding the identity of Stephen the Astrologer, see Wolska-Conus, "Stéphanos d'Athènes et Stéphanos d'Alexandrie," pp. 13–15; Magdalino, *L'orthodoxie des astrologues*, pp. 33–37; Roueché, "Stephanus the Alexandrian Philosopher," pp. 19–20.

53 Pingree, "Classical and Byzantine Astrology," pp. 238–39.

54 Neugebauer/van Hoesen, *Greek Horoscopes*, pp. 158–60.

55 Concerning the issue of the date and authorship of this text, see Tihon, "L'astronomie à Byzance à l'époque iconoclaste," pp. 183–90. M. Papathanassiou considers this

*of Mathematics*, Stephen underlined the decadence of astronomical and astrological studies in Constantinople as compared to Persian education. He noted a deviation of 5° in the longitude of the sun as calculated from Ptolemy's tables and his own times, and offered to revive these disciplines by adjusting Persian or Arabic tables to the coordinates of Byzantium and to the Byzantine calendar. Unfortunately, these tables have not been preserved.[56]

In Constantinople, Leo the Philosopher (d. after 869), also known as Leo the "Mathematician" (or Astrologer), who is famous for a legend according to which the Caliph sought his presence at the Persian court, presided over a public school established in the Magnaura palace toward the end of his life and owned a library that included astronomical and astrological works.[57] The astrological works associated with him reveal the limit of his skills in mathematics and generally reproduce the works of other authors.[58]

From the 9th century, several copies of astronomical manuscripts came down to us that preserved the works of Ptolemy and Theon; among them, four manuscripts of the *Handy Tables*. The reorganization of learning in the reigns of Theophilos (r. 829–842) and Michael III (r. 842–867) allegedly included the teaching of astronomy by Leo the Mathematician, but not much trace of astronomical activity remains from that period. Scholia found in these 9th-century manuscripts point to the utilization of the chronological tables of Ptolemy's *Handy Tables* in the late 8th century, but it is difficult to determine the extent to which the manuscripts of the *Almagest* or of its commentaries were actually studied. Nevertheless, the use of tables was necessary for astrologers as well, which may explain why several manuscripts of the *Handy Tables* were copied at the time.[59]

The 10th century, a period rich in the establishment of compilations in a number of other subjects, was surprisingly poor in astronomy.[60] Interest in astrology continued at the time, albeit sporadically. For instance, an imperial nativity was established on the basis of Ptolemy's *Tetrabiblos* and Dorotheos's

introduction and the early prognoses to be the work of Stephen of Alexandria ("Stephanos of Alexandria," pp. 193–201).

56 This deviation is related to the Egyptian calendar and not to the precession, as scholars sometimes forgot to take into account its five epagomenal days (Pingree, "Classical and Byzantine Astrology," p. 238–39). According to A. Tihon, these tables could refer to a work written after the late 8th century (Tihon, "L'astronomie à Byzance à l'époque iconoclaste," pp. 187–90).

57 Wilson, *Scholars of Byzantium*, pp. 79–84.

58 Pingree, "Classical and Byzantine Astrology," pp. 237–38.

59 Tihon, "L'astronomie à Byzance à l'époque iconoclaste," pp. 192–94.

60 On these Byzantine collections, see Odorico, "Cadre d'exposition / cadre de pensée—la culture du recueil," pp. 89–108.

poem, and cast for 3 September 905, a date that corresponds to Constantine VII's birth.[61] Finally, calculations of planetary longitudes for 906 clumsily adjusted the empirical methods of Vettius Valens to coincide with early 10th-century observations. While the methods of this unknown astronomer are questionable, they remain a rare source of evidence for observations in the history of Byzantine astronomy.[62]

## 3 Astronomy and Astrology in the 11th–12th Centuries

In the 11th and 12th centuries, the study of astronomy and astrology was rekindled. This period is marked not only by the translation, adaptation, and use of Arabic astronomical and astrological material, but also by a renewed interest in Ptolemaic works. Astrology fascinated the court, particularly in the reign of Manuel I (r. 1143–1180).[63] Several Byzantine chroniclers mention the presence of astrologers around the emperors. Anna Komnene's digressions about the subject in the *Alexias* are probably the most famous because she mentioned some of these astrologers by name, such as Symeon Seth, a scholar from Alexandria who flourished in the reign of her father, Alexios I (r. 1080–1118) and who, according to her, correctly predicted the death of Robert Guiscard in 1085.[64] Other documents, such as star catalogues for 1156 and 1161 also point to the likely Egyptian origin of the Arabic material that reached the Byzantines at the time.[65] Mostly only fragments of these works have been preserved, but they provided scholars with new observations, corrections, and better tables.[66]

A long scholium in Rome, Biblioteca Apostolica Vaticana, Vat. gr. 1594, a 9th-century manuscript of the *Almagest*, indicates that the astronomical tables of Alim, most certainly Ibn al-Aʿlam (d. 985), were already available in the first half of the 11th century.[67] An ephemeris for 1032–1036 and two horoscopes cast for some John Synadinos were also calculated on the basis of these tables for 1153 and 1162, and are reproduced in the Oxford, Bodleian Library, Seldenianus

61 Pingree, "The Horoscope of Constantine VII Porphyrogenitus," p. 230.
62 About these observations and methods, see Tihon, "La longitude des planètes," pp. 25–26.
63 Magdalino, *L'orthodoxie des astrologues*, pp. 91–132.
64 Anna Komnene, *Alexias*, VI.7.1–6, ed. Reinsch/Kambylis. See also Magdalino, "The Porphyrogenita and the Astrologers," pp. 15–31.
65 Tihon, "Les textes astronomiques arabes," p. 322.
66 Tihon, "Les sciences exactes," p. 397.
67 The scholium may be dated to *c.* 1032, but its copy was made in the manuscript in the 13th century (Tihon, "Tables islamiques à Byzance," pp. 402–03; see also Mogenet, "Une scolie inédite," pp. 220–21).

16.[68] Remarkably, the fragment attached to the 12th-century horoscopes shows that the tables of Alim were not only adapted to the Byzantine era, but also preserved its parameters more precisely than Arabic sources.[69]

The most important work of Arabic origin known in Byzantium before the translations of Persian and Arabic astronomical works by Gregory Chioniades at the end of the 13th century is an anonymous astronomical manual inspired by Arabic sources, but composed in Constantinople probably shortly after 1072. This manual does not explain astronomical theory, but offers instead *Methods for the Calculation of Divers Astronomical Principles* (*Μέθοδοι ψηφοφορίας διαφόρων ὑποθέσεων ἀστρονομικῶν*), such as solar eclipses. Examples are dated between 1060 and 1072, and apply to the city of Constantinople.[70] These methods feature important Arabic texts: the commentary of ibn al-Muthannā (10th century) on the astronomical tables of al-Khwārizmī (*c.* 840) and the tables of Ḥabash al-Ḥāsib (9th century). They also include unidentified material and Ptolemaic tables. Overall, they reflect their author's good grasp of technical terms in Greek, as he avoided the transliterations that characterized later Byzantine translations of Arabic works.[71] Furthermore, the text used the correct latitude of 41° for Constantinople, while 14th- and 15th-century treatises went back to a latitude of 43°, as given by Ptolemy.[72] From the same decade dates the only preserved Byzantine astrolabe, the astrolabe of Brescia (July 1062). Although made for the latitude of Constantinople, the instrument was influenced by Arabic astrolabes.[73]

As was mentioned above, the scholar Symeon Seth may have played an important role in the transmission of Arabic texts to Constantinople. He was himself the author of a star catalogue and of two short introductions to natural philosophy, the *Conspectus rerum naturalium* (*Synopsis of Natural Questions*) and *De utilitate corporum caelestium* (*On the Utility of Celestial Bodies*), which define basic astronomical concepts. In the *Synopsis*, Seth mentioned his observation of a solar eclipse in Egypt. He also used the value for the precession of

68 About these horoscopes, see Tihon, "Sur l'identité de l'astronome Alim," pp. 12–20; Caudano, "An Astrological Handbook," pp. 50–57.

69 Tihon, "Les sciences exactes," p. 396. Concerning the parameters of the tables of ibn al-Aʿlam, see Mercier, "The Parameters of the Zīj of Ibn al-Aʿlam," pp. 35–38.

70 Jones, *An Eleventh-Century Manual*, p. 11, where an edition and a translation of the manual may also be found (pp. 30–146).

71 Jones, *An Eleventh-Century Manual*, pp. 11–13.

72 Tihon, "Les sciences exactes," p. 397.

73 Jones, *An Eleventh-Century Manual*, pp. 17–18; description by Dalton, "The Byzantine Astrolabe at Brescia," pp. 133–46.

the equinoxes that had been determined by Arabic astronomers in the early 9th century (that is 0;0,54°/year).[74]

Finally, the Rome, Biblioteca Apostolica Vaticana, Vat. gr. 1056, a 14th-century copy of a 12th-century compilation, features—among many astronomical and astrological texts—a treatise on the astrolabe inspired by an Arabic source,[75] Symeon Seth's star catalogue and two others from 1156 and 1161, incomplete astronomical tables, the anonymous *Methods* mentioned above, as well as horoscopes cast for the accessions to the throne of Alexis I on 1 April 1081 and of Manuel I on 31 March 1143, and another made for 9 April 1106, which help dating this collection to the Komnenoi period.[76] This manuscript also reproduces an epitome of Hephaistion of Thebes (fl. *c.* 415) based on 11th-century material,[77] as well as chapters from the *Book of Questions to Masha'allah* (born *c.* 720–730) and other fragments of interrogational astrology, the translation of which was probably made by a scholar familiar with classical Greek astrological terminology.[78] From all the Arabic material still extant, it seems that Byzantine astronomers did not have at their disposal full translations or paraphrases of Arabic sources and relied essentially on excerpts, although the lack of fully preserved Arabic works is no evidence that the Byzantines were not aware of them.[79]

Along with this "modern" material, as the Byzantines themselves were calling Arabic sciences,[80] Byzantine scholars also showed renewed interest in Ptolemaic astronomy. This revival is visible in marginal notes to the *Handy Tables* (dated 1007–1008), but also in a testimony of Michael Italikos (mid-12th century) concerning his interest in celestial revolutions, or in Emperor Manuel I's gift of a manuscript of the *Almagest* to King William I of Sicily.[81] An

74 Jones, *An Eleventh-Century Manual*, pp. 16–17; Symeon Seth, *Conspectus rerum naturalium*, ed. Delatte (precession is discussed on pp. 46 and 53); Symeon Seth, *De utilitate*, ed. Delatte. The modern value is 0;0, 54°. The eclipse may have been the solar eclipse of 16 February 1086 (Tihon, "Les textes astronomiques arabes," pp. 320–21).

75 Tihon, "Traités byzantins sur l'astrolabe," pp. 331–32.

76 To these elements that help dating the prototype of this manuscript, we may add a note dated 1119/20 and another mentioning Manuel's death on 24 September 1179. For an analysis of the astronomical elements found in this manuscript, see Tihon, "Tables islamiques," pp. 405–13 and Pingree, "Gregory Chioniades and Palaeologan Astronomy," pp. 138–39, where the parameters for these horoscopes are given in note 29. On the star catalogues, see Kunitzsch, "Die arabische Herkunft."

77 Hephaistio, *Apotelesmatica*, ed. Pingree, vol. 2, pp. xxi–xxiii; edition on pp. 47–125.

78 Pingree, "The Byzantine Translations of Masha'allah," pp. 236–37.

79 Jones, *An Eleventh-Century Manual*, p. 19.

80 See for instance the scholium of Vat. gr. 1594 (Mogenet, "Une scolie inédite," p. 209) or Anna Komnene's description of astrological practices at the court discussed above.

81 Tihon "Les textes astronomiques arabes," p. 316; Wilson, *Scholars of Byzantium*, p. 214.

anonymous *Quadrivium* (*Anonymi logica et Quadrivium*) of 1007 with an astronomical section strongly grounded in Ptolemaic works, offers basic concepts of spherical astronomy as well as simple explanations for the use of the *Handy Tables*. It finishes with definitions that pertain to astrology but sets boundaries to the claims of astrologers.[82] Rudimentary notions of astronomy also appear in the works of Michael Psellos and Symeon Seth, which introduced their readers to a range of philosophical concepts.[83] These texts touched on a variety of cosmological issues and, by doing so, provided definitions for celestial phenomena, although they were less preoccupied by the technical aspects of celestial motion. Instead they focussed on their causes and nature, an approach that, for these authors, led to more essential enquiries about God.[84]

While none of these scholars questioned the necessity of studying astronomy, complaints against astrologers abounded, particularly in the reign of Manuel I, when astrological texts proliferated. Beside the horoscopes already mentioned above, the *themation* of John Synadinos for 5 February 1153 and its interpretation were also followed by an astrological handbook that compiled a variety of classical and Arabic sources. That "these *thematia* and their interpretation" were meant to "become a model for the moderns who wish[ed] to learn" points to the didactic and practical nature of this rudimentary work, the audience of which was most likely found among a literate public outside the realm of scholars and professional astrologers.[85] The text is also reminiscent of astrological poems that circulated at the time, especially John Kamateros's *Introductio in astronomiam* (*Introduction to Astronomy*) and *De zodiaco*, a *Poem about the Zodiacal Circle*, both dedicated to Manuel I, as well as the verses offered by Constantine Manasses to Manuel I's sister-in-law, the Sebastokratorissa Irene.[86] The emperor himself became entangled in a controversy about the legitimacy of astrology with the monk Michael Glykas after penning a long apology on behalf of astrology.[87] Interest in astrology was not confined to the court or to lay milieus, however, it also touched clerics, as the bitter complaint of Peter the Philosopher about Patriarch Luke Chrysoberges (1157–1169)

82 *Anonymus* 1007, ed. Heiberg, pp. 104–22.

83 See above, pp. 214–15; Michael Psellos, *De omnifaria doctrina*, ed. Westerink.

84 *Anonymi Miscellanea Philosophica*, ed. Pontikos, pp. xlvii–xl.

85 Caudano, "An Astrological Handbook," p. 53; on the content of this compilation, see pp. 52–57 in the same article.

86 Contrary to the handbook, these poems relied exclusively on classical or Byzantine material (Caudano, "An Astrological Handbook," pp. 57–62).

87 Manuel's apology was written in response to a polemical tract from a monk of the Pantokrator monastery accusing astrologers and their supporters of heresy (Magdalino, *L'orthodoxie des astrologues*, pp. 114–26).

indicates.[88] Open attempts to dampen this enthusiasm appear in a range of texts aimed at establishing clear boundaries between the work respectively of the astronomer and of the astrologer, for instance in the *Quadrivium* of 1007, the works of Peter the Philosopher, or in a letter of Michael Glykas to Alypios.[89] The medical use of astrology, however, was generally acknowledged. In spite of such practical usefulness, the 12th-century canonist Theodore Balsamon reinterpreted canon 36 of the synod of Laodicea (364) on the study of mathematical arts as a prohibition against Christians studying astronomy altogether. Zonaras, another canonist, even recommended that churchmen should not show excessive interest in any of the four disciplines of the *Quadrivium*.[90]

These comments did not prevent anyone from doing so of course, but such an atmosphere may have prompted the revival of literal interpretations of the Bible that had characterized the theology of the Antiochene School between the 4th and 6th centuries, in, for instance, the commentaries on Genesis by John Chrysostom and Severianos of Gabala, or in the *Christian Topography* of Kosmas Indikopleustes. According to this biblical model of the world, the universe took the form of a vaulted box and the earth formed a flat support for the world. The luminaries disappeared at night behind a screen or a conic mountain. Traces of such beliefs are visible in the chains of commentaries on the Bible copied in the 11th and 12th centuries, as well as in letters whose authors felt the need to defend as orthodox the spherical shape of the world.[91] While such discussions belong to theology and cosmology and had little impact on astronomy, they testify to the presence of alternative worldviews in Byzantine society. This biblical understanding of the world was transposed into a rather curious astronomical treatise written by Peter the Philosopher in the 12th century. On the basis of the Antiochene model of the world, Peter the Philosopher discussed issues common to many introductory astronomical manuals, including eclipses, lunar phases, seasons, the length of days and nights, or the revolution of the planets. In a confusing section, he even offered what he considered to be a precise method of calculating the horoscope.[92] The revival of a biblical model of the world was not prominent in Byzantium, yet this trend is undeniably inscribed in a context that also sought to establish the orthodox

88 Analysis and translation of this letter in Caudano, "Le ciel," pp. 22–28, 48–51. About astrology in ecclesiastical milieus, see Magdalino, *L'orthodoxie des astrologues*, pp. 126–27.

89 *Anonymus* 1007, ed. Heiberg, pp. 120–22; Ieraci Bio, "Michele Glica"; Caudano, "Le ciel," pp. 28–29, 52–53.

90 Fögen, "Balsamon on Magic," pp. 99–115; Ieraci Bio, "Michele Glica," pp. 184–85.

91 About this issue, see Caudano, "Un univers sphérique ou voûté," pp. 66–86.

92 Edition, translation and analysis of this treatise in Caudano, "Le ciel," pp. 28–73.

boundaries of knowledge to the point of questioning the premises of the prevailing spherical model of the world.[93]

## 4 The Empire of Nicaea and the Palaiologan Period (13th–15th c.)

The study of astronomy suffered from the fall of Constantinople to the crusaders in 1204 and the fragmentation of Byzantine authority into different states, although mathematical education could still be gained at the newly established court in Nicaea. The most prominent scholars of the Nicaean court were the monk Nikephoros Blemmydes (1197–*c.* 1272), who was born in Constantinople, and his student George Akropolites (1217–1282), who taught Theodore II Laskaris (r. 1254–1258) and became head of the Imperial School in Constantinople after the recovery of the capital by the Byzantines in 1261.[94] While there was no lack of interest in the heavens at the Nicaean court, there is little evidence for the practice of astronomy or astrology. In fact, no astrological or astronomical calculations remain from this period. The difficulty that George Akropolites faced in 1239, when he was contradicted vociferously by a court physician in front of Empress Irene about the cause of solar eclipses, suggests that the level of education in astronomy was not particularly high outside scholarly circles.[95] Yet, the same George Akropolites also believed that this eclipse and the presence of a comet six months before announced Irene's death on that year.[96] Celestial portents were precisely the subject of an Arabic version of an apocalypse of Daniel, translated into Greek by Alexios in 1245, an inhabitant of Constantinople who had been captured by the Arabs.[97]

In their works, both Blemmydes and Theodore II Laskaris emphasized the importance of astronomy and their own knowledge of this science. They also clearly distinguished astronomy from astrology and openly despised the latter.[98] At this time, preference was given to the physics of the heavens rather

93 Caudano, "Le ciel," pp. 46–47; see also chapter 7 of this volume.

94 Bydén, *Theodore Metochites*, pp. 29–30.

95 On the teaching of science, see chapter 2 of this volume.

96 Tihon, "Astrological Promenade," pp. 267–68.

97 Magdalino, *L'orthodoxie*, p. 149.

98 Magdalino, *L'orthodoxie*, pp. 136–39. Both authors used "λήρους" (Blemmydes) / "ληρωδήματα" (Laskaris) or "nonsensical" to define astrology. Theodore Laskaris also qualified this science as unscientific: "τῶν ἀνεπιστημόνων ἐπιστημῶν" (Nikephoros Blemmydes, *Curriculum vitae*, I.8, line 10, ed. Munitiz; Theodore II Laskaris, *Epistulae CCXVII*, ed. Festa, letter CXXXI, line 21). Elsewhere, the emperor conceded that Byzantine scholars lacked command of astronomy and that even their knowledge of astrology was faulty (*ibidem*, letter CXXV, lines 33–34).

than their mathematical laws. By doing so, however, Blemmydes's compendium of natural philosophy, the *Epitome physica* (chapters 24–31), and the second book of Theodore II Laskaris's Κοσμικὴ Δήλωσις (*Explanation of the World*) on the heavens, also touched on broader astronomical questions.[99]

The recovery of Constantinople by Michael VIII in 1261 signalled a renewal in mathematical studies.[100] The Palaiologan Renaissance, as it is also known, was indeed the most productive period in this field, particularly in the reign of Andronikos II (r. 1282–1328), who supported the study of the *Quadrivium* in general and of astronomy in particular.[101] An influx of foreign texts led to interesting comparative work after the introduction of Persian tables and methods around 1300, which in turn may have partly stimulated this revival in astronomy. The Latin occupation also left some traces. Already in the 14th century, but more particularly in the 15th century, Latin and Jewish texts were adapted to Byzantine coordinates and calendar as well. For some Byzantine scholars, though, these comparisons had no other objective than to patch up the increasingly weak Ptolemaic methods and tables, a discussion that was ultimately introduced into Western intellectual circles as the Byzantine empire crumbled under the Ottoman conquests.

The restoration of mathematical education in the capital did start before Andronikos's reign, however, and was in the hands of the civil official George Akropolites who, along with other subjects, taught arithmetic and geometry.[102] Among his pupils was George Pachymeres who later became a teacher at the Patriarchal School. In 1300, he wrote a *Quadrivium* where astronomical and astrological concepts are explained in greater depth than in its predecessor of 1007, from which he also took his inspiration.[103] While rejecting astrological predictions, Pachymeres still believed in the ominous role of celestial bodies, just as his teacher George Akropolites did before him.[104] Another interesting figure is the monk Maximos Planoudes (*c.* 1255–*c.* 1305), who was reputed for his philological work and translated the *Commentary* of Macrobius on Cicero's *Dream of Scipio* into Greek.[105] He also wrote a mathematical treatise, Ψηφοφορία

99 Bydén, *Theodore Metochites*, p. 224. Nikephoros Blemmydes, *Epitome physica*, ed. Wegelin; Theodore II Dukas Lascaris, *Κοσμικὴ Δήλωσις*, ed. Festa.

100 See also chapter 3 of this volume.

101 Bydén, *Theodore Metochites*, pp. 260–62.

102 See also Tihon, "Astrological Promenade," pp. 267–69.

103 George Pachymeres, *Quadrivium*, ed. Tannery/Stephanou, pp. 396–99. See also Magdalino, *L'orthodoxie des astrologues*, p. 147.

104 Tihon, "Astrological Promenade," pp. 271–73.

105 Wilson, *Scholars*, 230.

κατ' Ἰνδοὺς ἡ λεγομένη μεγάλη (*The Great Calculation according to the Indians*), and copied the works of Cleomedes and Aratos, as well as part of Theon's *Commentary* on the *Almagest*.[106] These scholars were not astronomers *per se*, but they contributed improvements in the knowledge of mathematics necessary to the practice of astronomy and astrology.

The study of astronomy under the patronage of Andronikos II found fuller expression in the works of the court official Theodore Metochites, who held the important offices of Grand Logothetes, then of Mesazon to the emperor. While not particularly innovative, his Στοιχείωσις ἀστρονομική (*Abridged Elements of Astronomy*, *c.* 1317) offered a comprehensive introduction to Ptolemy's *Almagest* in two books.[107] Metochites's work seems particularly to have encouraged the further study of Ptolemaic astronomy, although Metochites alone was not responsible for a revival in astronomical studies. His exclusive emphasis on Ptolemy also occurred at a time when a range of Persian astronomical works became available, as we shall see below. Metochites was certainly aware of the importance of mathematical work done in the East, but he chose not to use such texts.[108] Metochites's impact on the study of Ptolemaic astronomy is undeniable. In a bitter and protracted controversy with his political rival, the scholar Nikephoros Choumnos (*c.* 1260–1327) on the relative merits of astronomy and physics, Metochites suggested that mathematical disciplines, astronomy among them, were superior to all other sciences. He also decried Choumnos's ignorance of the field and his reliance on a Platonic cosmology that contradicted Ptolemy's precession of the equinoxes by questioning the number of celestial spheres. These arguments, compounded with Metochites's political influence, ensured the ultimate victory of his position on astronomy in this debate.[109] Yet, despite Metochites's importance in the 14th-century revival of astronomy, his introduction to the field did not arouse much enthusiasm among his contemporaries, most likely because of the Logothetes's difficult style.[110] This may explain the small number of manuscripts that preserved this work.

106 Mondrain, "Maxime Planude, Nicéphore Grégoras et Ptolémée," pp. 316–17.

107 The first five chapters of Book 1 are edited in Bydén, *Theodore Metochites*, pp. 417–74; Chapters 5–30 in Theodore Metochites, Στοιχείωσις ἀστρονομική, ed. E.A. Paschos/C. Simelidis (Book 2 remains to be published).

108 This does not mean necessarily that he despised them, as has often been claimed (Bydén, *Theodore Metochites*, pp. 226, 257–62).

109 Ševčenko, *Études*, pp. 68–117; Nicolaidis, *Science and Eastern Orthodoxy*, pp. 85–89.

110 The scholar John Chortasmenos is a notable exception (Ševčenko, *Études*, pp. 44–45, 111–13).

The importance of Ptolemaic astronomy in the early Palaiologan period is also visible in the works of one of Metochites's students, the polymath Nikephoros Gregoras. Among other works of history, hagiography, or theology, Gregoras also calculated and predicted several eclipses in the 1330s, using the *Almagest* and the *Handy Tables*. His work launched a trend for eclipse calculations among Byzantine scholars.[111] He also wrote a treatise *On the Construction of the Astrolabe* (*Astrolabica*),[112] and debated astronomical matters at length in his correspondence. Overall, letters at the time—as in the debate between Metochites and Choumnos—reveal the growing interest in astronomy in Byzantine intellectual circles, and show the discipline as a field of scholarly dispute notably regarding the capacity of astronomers to correctly predict the date of solar eclipses.[113] That such debates happened in the form of letters is also notable, as Byzantine epistolography was not always confined to the private sphere. Some of these texts circulated and, therefore, engaged more people than the number of their alleged recipients would suggest.[114]

One of Gregoras's correspondents, the Cypriote George Lapithes, pointed out to Gregoras the imprecision of the *Handy Tables* and his aim of improving them after his contact with Latin scholars.[115] Lapithes himself was responsible for a Byzantine adaptation of the *Toledan Tables* in *c.* 1340 and, according to Gregoras's *Roman History*, was also strongly interested in astrology.[116] In fact, the *Toledan Tables* were the object of a later Byzantine adaptation, a treatise on the *Latin Tables*, established by Demetrios Chrysoloras (*c.* 1380). The use of the longitudes of Cyprus and Paris in Chrysoloras's work indicates that the treatise

111 Tihon, "Les sciences exactes," p. 399; Mogenet/Tihon, *Barlaam de Seminara*, p. 153. For instance, Nicholas Rhabdas announced to his correspondent a solar and a lunar eclipse for 1321; an anonymous scholar predicted a lunar eclipse for 19 April 1334 (Tihon, "Nicolas Eudaimonoioannes," pp. 152–54). About the traces of Nikephoros Gregoras's work on astronomical texts in Byzantine manuscripts, see Mondrain, "Maxime Planude, Nicéphore Grégoras et Ptolémée," pp. 320–22.

112 Tihon, "Traités byzantins sur l'astrolabe," p. 340; Nikephoros Gregoras, *Astrolabica*, ed. Delatte.

113 For instance in Gregoras's letter with an anonymous correspondent, possibly the Calabrian monk Barlaam, although this identification has been recently called into question (about these issues, see Manolova, *Discourse of Science and Philosophy*, pp. 108–29; Mogenet/Tihon, *Barlaam de Seminara*, pp. 156–57). Both Gregoras and Barlaam also discussed the possibility of reforming the calendar and the calculation of the date of Easter, considering that Ptolemy's value of the tropical year was incorrect (Tihon, "Les sciences exactes," pp. 399–400; Tihon, "Barlaam de Seminara," pp. 362–411).

114 For instance one of Gregoras's astronomical letters was circulated and read in public (Manolova, *Discourse of Science and Philosophy*, pp. 110–11).

115 Manolova, *Discourse of Science and Philosophy*, pp. 116–17.

116 Pingree, "The Byzantine Version of the *Toledan Tables*," pp. 87–132.

came to Constantinople through the island, which was then under French authority, but nothing indicates that these tables were ever used.[117] In addition to the works of these scholars, the number of scholia attached to Ptolemy's works in Byzantine manuscripts from the late 13th to the 15th centuries confirms the strong interest in Ptolemy among Byzantine astronomers.[118]

The revival of Ptolemaic astronomy coincided with the growing influence of Persian astronomy. According to the preface of George Chrysokokkes's *Persian Syntaxis* (*c.* 1347),[119] a Byzantine scholar, George Chioniades, had been attracted to Persia to perfect his study of astronomy. At the time, the reputation of the observatory of Maragha established by the Mongol khan Hulagu in 1259 attracted many foreign astronomers. Chioniades left Constantinople for Trebizond on the Black Sea, a place well situated for exchanges with Persia. Having received financial patronage from Alexios II Komnenos (r. 1297–1330), Chioniades left to study in Persia and came back with a number of astronomical books that he set out to translate.[120] The details of this story are not entirely clear—it is indeed likely that several translators were at work—but it is undeniable that the late 13th and 14th centuries saw the appearance of a range of Greek manuscripts with translations of Persian material. They include, among other works, Byzantine adaptations of the *Zīj al-ʿĀlāʾī* of al-Fahhad (*c.* 1176) through the teachings of Shams ad-Dīn al-Bukhārī (*c.* 1293–1296),[121] the *Zīj as-Sanjarī* of al-Khāzinī (*c.* 1115), tables from 1093, calculations made in Constantinople that range from 1298 to 1302 and that were based on the Persian tables, as well as the treatise on the astrolabe by (maybe) Shams Bukhārī (*c.* 1302).[122] From around 1300 we can date a text and planetary diagrams inspired by the 13th-century astronomer Naṣīr al-Dīn al-Ṭūsī's *al-Tadkhira* or *Memoir on the Science of Astronomy* (*c.* 1260s) and that reproduce the Ṭūsī couple.[123] Unlike the preceding period when an influx of Arabic material was visible, many

117 Tihon, "L'astronomie byzantine à l'aube de la Renaissance," pp. 252, 259–61.

118 Tihon, "Les science exactes," p. 399.

119 H. Usener, "Ad historiam astronomiae symbola," in *Kleine Schriften*, vol. 3, Leipzig 1914, pp. 356–57; transl. Tihon, "Les sciences exactes," pp. 401–02.

120 Tihon, "De même qu'on peut voir les abeilles," pp. 285–86. His letters indicate that he became bishop of Tabrîz (Pingree, "Gregory Chioniades," p. 141).

121 Gregory Chioniades, *Zīj al-ʿĀlāʾī*, ed. Pingree.

122 About these works, see Pingree, "Gregory Chioniades," pp. 141–44; Tihon, "Traités byzantins sur l'astrolabe," pp. 333–35.

123 Rome, Biblioteca Apostolica Vaticana, Vat. gr. 211, fols. 115–21 (edition E.A. Paschos/ P. Sotiroudis, *The Schemata of the Stars. Byzantine Astronomy ca. 1300*, Singapore 1998). According to J. Ragep, the version of the Ṭūsī's Tadkhira accessible to the Byzantines reproduced an "earlier [Persian] version with a significant error" (Ragep, "From Tūn to Toruń," p. 176).

astronomical terms in these works were transliterated into Greek. These translations were, therefore, more difficult to use for Greek-speaking astronomers. Anonymous ephemerides were also made in Trebizond from Persian tables and give for one year (1 March 1336–1 March 1337) the positions of all planets every ten days, as well as their aspects. Its author may have been Manuel of Trebizond, the teacher of George Chrysokokkes.[124] That the purpose of these ephemerides was astrology is indicated by the predictions found in the marginal comments to the astronomical calculations.[125]

Chrysokokkes's *Persian Syntaxis*, largely inspired by Ṭūsī's *Zīj-i Īlkhānī*,[126] was the most successful of these texts, because the terminology was more Hellenised and the material closer to the Byzantine astronomical curriculum as defined in Theon's *Small Commentary*, i.e. the calculations of longitudes and latitudes, syzygies and eclipses, as well as ephemerides and *thematia*. Yet, this Byzantine adaptation was not devoid of errors and misunderstandings. For instance, the Byzantines mixed the Persian and Ptolemaic procedures in the calculation of the time separating the true from the mean syzygies, which causes an error of half an hour in the final results. Other mistakes, in addition to this one, made it such that the tables of Ptolemy sometimes gave better results when calculating syzygies. Yet, no Byzantine astronomer seems to have noticed or to have attempted to correct these methods.[127]

Chrysokokkes considered astrology the ultimate purpose of his text, because of its usefulness in medicine, an argument that he had also imparted to Chioniades.[128] As we have seen, this argument had been used before to justify the study of astrology in the 12th century.[129] Scholars like Metochites and Gregoras also believed in the influence of the stars on natural phenomena, but not on individual fate. In Gregoras's time, the predictability of eclipses, which were often interpreted as portents, sometimes worried the authorities, tied as they were to heralding disasters. Gregoras was notably enjoined by the emperor not to reveal the prediction of the solar eclipse of 1333. In his own chronicle, Gregoras himself saw eclipses as divine portents.[130]

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124 Tihon, "De même qu'on peut voir les abeilles," pp. 286–87. Ed. Mercier, *Almanac*.

125 Tihon, "Astrological Promenade," p. 278.

126 Tihon, "Les tables astronomiques persanes," p. 481; see also Mercier, "The Greek 'Persian Syntaxis.'"

127 Tihon, "L'astronomie byzantine à l'aube de la Renaissance," pp. 246–50.

128 On medicine, see chapter 10 of this volume.

129 In his own justification for astrology, Chrysokokkes refers to emperor Manuel I's *Apology of Astrology* (Tihon, "Astrological Promenade," pp. 274–75, 279–80).

130 Tihon, "Astrological Promenade," pp. 280–88.

In contrast, by firmly condemning astrology and producing a synthesis of the two currents of Byzantine astronomy, Theodore Meliteniotes, head of the Patriarchal School, ensured persistent interest in astronomy within the Byzantine clergy. His astronomical manual in three books, *De astronomia libri III* or Τρίβιβλος ἀστρονομική (*Three Books on Astronomy*, also known as *Tribiblos*, *c.* 1352), was probably geared to the mathematical teaching of the clergy.[131] It offers (1) an introduction to the basic arithmetical operations within the sexagesimal system and a treatise on the astrolabe, (2) an introduction to Ptolemaic methods from the *Almagest* and the *Handy Tables* with examples, and (3) a paraphrase of George Chrysokokkes's *Persian Syntaxis* that included the Persian tables but reproduced the mistakes of its predecessor.[132] By merging the two trends in his manual, Ptolemaic and Persian, but keeping them separate in different books, Meliteniotes is representative of many other Byzantine astronomers who compared Alexandrian and Persian tables and methods without offering constructive criticism. Indeed, while they criticized Ptolemy's tables, these astronomers preserved them as well, precisely because the Persian methods expounded by Chrysokokkes were inexact. Similarly, Meliteniotes was aware that Ptolemy's tables were outdated. Yet, he neither criticized them openly nor explicitly compared their results with those obtained with the Persian tables. Implicitly, though, the point of the *Tribiblos* was probably the search for some harmony between the two methods.[133]

The necessity also to adapt tables to the Byzantine calendar encouraged some scholars to create updated tables. The monk Isaac Argyros was the author of two treatises on the *New Tables* for the sun and the moon, which start on 1 September 1367 and are adapted to the coordinates of Constantinople. They used one, the *Handy Tables* and the other, the *Almagest*. Although they were based on Ptolemaic parameters and methods, Argyros's tables also used simplified Persian tables for the parallax. They were geared primarily toward the calculation of syzygies, an issue that grabbed the attention of many clerics because it was linked to the Easter computus.[134] Argyros also claimed to have adapted planetary tables, although they have not been preserved. Finally, he

131 Tihon, "Sous la plume de Jean Chortasmenos," p. 158.

132 Edition Leurquin, *Théodore Méliténiote*.

133 For instance, the same examples are calculated by the two methods. Regarding some of these attempts to harmonize the two sets of tables, see Tihon, "Sous la plume de Jean Chortasmenos," pp. 157–84; Tihon, "L'astronomie byzantine à l'aube de la Renaissance," pp. 247–51.

134 Tihon, "De même qu'on peut voir les abeilles," p. 287. The focus on the calculation of the date of Easter may also explain the presence of scholia on the calculation of the equinoxes dated from 1352–1356 (Tihon, "Sous la plume de Jean Chortasmenos," p. 163).

wrote a *Treatise on the Date of Easter*, as well as a *Treatise on the Astrolabe* (1367/1368) based on the previous works of Gregoras and Meliteniotes.[135] To Isaac Argyros's name is sometimes attached the Παράδοσις εἰς τοὺς περσικοὺς κανόνας τῆς ἀστρονομίας (*Instruction on the Persian Astronomical Tables* or *Paradosis*). This successful manual, based on Chrysokokkes's *Persian Syntaxis* and dated 1352, explained the use of the Persian tables and is likely to be the text used by Meliteniotes for the third book of the *Tribiblos*.[136] Other attempts to adapt tables were made in the late 14th and 15th centuries, either based on the *Handy Tables* or on Persian tables, but none of them gave satisfactory results.[137]

While prominent astronomers like Metochites, Gregoras, and Meliteniotes had decried the claims of astrologers, astrology had a revival in the Palaiologan period, as is attested by the important number of astrological texts that can be found in 14th- and 15th-century Byzantine manuscripts. In the early 14th century, an anonymous Christian apology for astrology in the form of a dialogue, *De astrologia dialogus* (*Dialogue on Astrology*, also known as *Hermippos*), strove to reconcile the belief in the influence of the stars over the natural world with the dogmas of divine providence and free will.[138] The anonymous author went as far as claiming that astrology was a means surer than asceticism of contemplating the Divine, a position that was strongly condemned by the hesychast monk Gregory Palamas in 1338.[139]

The activities of the astrologer John Abramios and his school appear in a range of astrological texts, horoscopes, and eclipse calculations and may be dated between 1370 and *c.* 1410. This astrological school left its mark in several manuscripts, since they revised the texts of classical astrological works and the translations of some Arabic material.[140] Like the astronomers, these astrologers were aware of the need to update Ptolemaic and Persian tables, and also produced comparative eclipse calculations using both methods, in an unsuccessful attempt to combine them and obtain better results. According to

135 Tihon, "Les sciences exactes," pp. 405–06. Isaac Argyros was not the only Byzantine author to use or comment on Gregoras's *Treatise*. Scholia are attributed to an otherwise unknown monk, Makarios. In the middle of the 15th century, Matthew Kamariotes also commented on the text (Tihon, "Traités byzantins sur l'astrolabe," pp. 326, 349).

136 Twenty-seven manuscripts have been identified. An edition, translation and commentary are in preparation by Alberto Bardi. In the meantime, the reader can refer to his dissertation (Bardi, *Persische Astronomie*, pp. 108–208).

137 Manuscripts only preserved fragments of these anonymous works (see Tihon, "L'astronomie byzantine à l'aube de la Renaissance," pp. 251–52).

138 *Hermippos*, ed. Kroll/Viereck.

139 Magdalino, *L'orthodoxie des astrologues*, pp. 154–57.

140 Pingree, "The Astrological School of John Abramius"; Pingree, *From Astral Omens to Astrology*, pp. 74–76.

D. Pingree, the astrologer John Abramios may be behind a group of texts on syzygies that had the open intention of correcting Ptolemy's parameters, but compared instead the results of eclipse calculations based on Argyros's *New Tables* and Meliteniotes's Persian tables. Examples range from 1376 to 1408, but this comparative endeavour never delivered the expected corrections.[141]

The patriarchal notary, copyist, and teacher John Chortasmenos (fl. 1404–1414), also participated in this comparative project by copying or calculating himself a number of eclipses and syzygies by different methods, such as the *Almagest*, the *Handy Tables*, Theon's *Small Commentary*, or Isaac Argyros's *New Tables* among others.[142] Chortasmenos's interests in astronomy matched the preoccupations of many of his contemporaries in this field. While deeply attached to Ptolemaic astronomy, the encounter with the Persian tables made him acutely aware of the need for more correct tables and adjusted methods.[143] A rare admirer of Metochites, Chortasmenos also copied and rearranged the *Tribiblos* of Meliteniotes in such a way as to have examples and theory facing each other.[144] Chortasmenos instilled in his students, Mark Eugenikos and Bessarion, a sustained interest in astronomy and sent them to the Neoplatonist philosopher George Gemistos Plethon (*c.* 1360–1452) in Mistra to perfect their study of this science.[145]

To Plethon's name is attached the most original contribution to Byzantine astronomy. His tables (*c.* 1433), designed for the coordinates of Mistra, were largely based on the parameters of Ptolemy's *Almagest* and of the Hebrew version of al-Battānī's *Zīj* by Immanuel Bonfils. The existence of an anonymous

141 Pingree, "Some Fourteenth-Century Byzantine Astronomical Texts," pp. 105–07; Pingree, "The Astrological School of John Abramius," p. 198. Against this attribution, see Tihon, "L'astronomie byzantine à l'aube de la Renaissance," pp. 273–74.

142 The range of works that he copied in his two large astronomical compendia (Rome, Biblioteca Apostolica Vaticana, Vat. gr. 1059 and Urb. gr. 80) is equally varied and includes classical and early Byzantine works, such as Proclus's *Hypotyposis*, John Philoponos's *Treatise on the Astrolabe*, the astronomical treatise of Stephen of Alexandria, as well as 14th-century works, such as Demetrios Chrysoloras's adaptation of the Alfonsine tables or Metochites's *Stoicheiosis* (about these manuscripts, see Canart/Prato, "Les recueils organisés par Jean Chortasmenos," pp. 125–46).

143 Chortasmenos calculated the solar eclipse of 15 April 1409 and the lunar eclipse of 20 March 1410 with three different methods in Vat. gr. 1059: the *Almagest* (ff. 7r–15v); Persian methods and tables (ff. 26v–29r); and a combined method largely inspired by Isaac Argyros's *New Tables* (ff. 90r–101r). The latter may reveal an attempt to adjust the results by tampering with the velocity of the moon but, by the author's own admission, the primary goal of combining methods and tables was convenience (Vat. gr. 1059, f. 95v; Caudano, "Le calcul de l'éclipse de soleil du 15 avril 1409," pp. 238–41).

144 Leurquin, *Théodore Méliténiote*, vol. 1, pp. 51–67.

145 Caudano, "Le calcul de l'éclipse de soleil du 15 avril 1409," pp. 215–18.

treatise and tables that are close to Plethon's work, but that were made for the meridian of Constantinople and that used the parameters of the *Persian Syntaxis*, suggests a first attempt at establishing this work *c.* 1412–1415, which was again revised in 1446 and for which different parameters were used.[146] Plethon's manual was strongly embedded in his idea of reviving ancient pagan religion. In conformity with the old Greco-Roman calendar, Plethon's tables used lunar months. His lunisolar year, which varied from 12 to 13 months, started at the first full moon after the winter solstice. All longitudes were therefore computed from 0° Capricorn, rather than the more usual start in 0° Aries. Overall, in spite of all its originality, Plethon's lunisolar calendar, thus his tables, would have been very difficult to use by his contemporaries who relied on the Julian calendar. The manual itself also offered few instructions about his method.[147]

Plethon's work also symbolizes a time when some Byzantine astronomers became more conversant with Jewish astronomy. Plethon himself was taught by a Jew at the Ottoman Court.[148] The study and adaptation of Jewish tables by the Byzantines in the 15th century belonged to the larger goal of having better tables to calculate syzygies and eclipses. Indeed, most of these Jewish texts applied to the motion of the sun and the moon, but not the planets.[149] The influx of Jewish works in Byzantium may be explained by active Jewish communities in Constantinople, Crete, and Thessalonica, who also worked on Byzantine adaptations of the Persian tables.[150] These works include Jewish Provençal treatises, notably the *Six Wings* of Immanuel Bonfils of Tarascon (*c.* 1365) translated by Michael Chrysokokkes (*c.* 1434/5) and the *Cycles* of Jacob ben David Bonjorn, compiled for the latitude of Perpignan (*c.* 1361) and translated by Mark

146 Tihon, "The Astronomy of George Gemistus Plethon," pp. 109–16; Mercier, "The Astronomical Tables of George Gemistus Plethon," pp. 124–27. Plethon, *Astronomical Treatise*, ed. Tihon/Mercier. According to M. Cacouros, these early tables may have emerged from the scholarly milieu of John Chortasmenos (Cacouros, "A. Tihon—R. Mercier (eds.), *Georges Gémiste Pléthon*," pp. 334–35).

147 Tihon, "The Astronomy of George Gemistus Plethon," pp. 111–14.

148 Tihon, "The Astronomy of George Gemistus Plethon," p. 109.

149 This statement should not be generalized. The *Six Wings* of Immanuel Bonfils also included a set of tables for planetary motions (Goldstein, "Astronomy among Jews," p. 138).

150 The role of Jewish communities in the scientific exchanges between Byzantines, Latins, and Ottomans in the Eastern Mediterranean is essential to understand the scholarly networks of the Renaissance. In Thessalonica (*c.* 1373), Solomon ben Elijah translated Chrysokokkes's *Persian Syntaxis*, a text later commented by Mordechai Khomṭiano (Comtino) in Constantinople (*c.* 1425). A Latin translation of the text was made in Venetian Crete, possibly in the Jewish community, and may be dated *c.* 1408–1422 (Morrison, "Jews as Scientific Intermediaries," pp. 212–14; Tihon, "The Astronomy of George Gemistus Plethon," p. 116).

Eugenikos (*c.* 1431).[151] Finally, the solar and lunar tables of Isaac ibn al-Ahdab (*c.* 1391), a Spaniard in Sicily, were also adapted by Matthew Kamariotes (d. 1490). Nothing indicates that these works were translated directly from Hebrew. It is indeed possible that they were obtained through a Latin intermediary, at a time when exchanges with the Latin world were intensified by the negotiations on the Union of Churches.[152]

According to a famous story, during the Council of Ferrara-Florence in 1438–1439, Plethon himself made a strong impression on Western intellectuals in his stark defence of Plato against Aristotle, views that may have influenced the establishment of the Platonic Academy in Florence.[153] As the history of the Byzantine empire came to a close, its scholars continued their work in Western and Ottoman circles. Plethon's student, Cardinal Bessarion supported Ptolemaic astronomy in the humanist circles of Peuerbach and Regiomontanus, and encouraged translations of the *Almagest* and of Theon's *Commentaries*.[154] In 1452, George of Trebizond offered a Latin translation of the *Almagest* to Pope Nicholas V, which he capped with a commentary that (rightfully) emphasized arithmetical errors in Theon's commentary and, in doing so, criticized the works of Geber, Levi ben Gerson, and Thābit ben Qurrah. In turn, his criticisms were badly received. He became so embroiled in a bitter dispute with Bessarion and his circle, that the publications of his work was prevented. He later attempted to offer a Greek translation of his mathematical comments to Sultan Mehmet II, but was unsuccessful in his endeavour once again.[155]

Byzantine astronomers did not cease their work after the fall of Constantinople to the Ottomans in 1453: manuscripts were still copied, ephemerides produced, and new commentaries written. Overall much work remains to be done on Byzantine manuscripts to identify and analyze scholia, excerpts, and calculations.[156] Some fundamental texts, such as Chrysokokkes's *Persian Syntaxis* or Argyros's *New Tables*, are still unpublished. Late Byzantine manuscripts also reproduced many works that, while not strictly astronomical, point to the circulation of a wide range of beliefs about the universe within the literate

151 Solon, "The *Six Wings* of Immanuel Bonfils," pp. 1–20; Tihon, "Astronomie juive à Byzance."

152 Tihon, "De même qu'on peut voir les abeilles," 287–288. Concerning the issue of the Greek and Latin translations of some of these texts, see Taube, "Transmission of Scientific Texts," p. 335 n. 51–52.

153 Hankins, "Cosimo de' Medici and the 'Platonic Academy,'" pp. 144–45.

154 Rigo, "Bessarione, Giovanni Regiomontano e i loro studi su Tolomeo."

155 Tihon, "De même qu'on peut voir les abeilles," p. 289. The standard work on George of Trebizond remains Monfasani, *George of Trebizond*.

156 A list of authors, texts, and manuscripts can be found in Tihon, "L'astronomie byzantine à l'aube de la Renaissance."

population of the Palaiologan period and beyond. Among these texts, one of the most popular attributed an ovoid shape to both the earth and the cosmos. Even the box-shaped universe inspired by the Bible still appeared in late Byzantine manuscripts, although to a lesser extent.[157] Other works alluded to the presence in the ninth sphere of the heavens of a dark snake-like star, to which were attributed a range of natural disasters. In yet other texts, probably of Syriac origin, eclipses were explained by the interposition of a star called "head and tail" between the sun and the moon.[158] While the importance of such minor works should not be exaggerated, they should not be ignored either: in some cases, these were the only introductions available to natural philosophy.[159] Once again, a more systematic study of the manuscripts is needed to contextualize these works and determine their audience.

As the heirs of Ptolemy's monumental works of mathematical astronomy, Byzantine astronomers displayed a strong attachment to and pride in a Hellenistic tradition that never left them. The convenient location of the Byzantine empire at the crossroads of the Latin and Islamic worlds also facilitated exchanges and made these astronomers keenly aware of the existence of new observations and methods. Translations of Arabic and Persian works, and their adaptations to Byzantine coordinates show how much some embraced other tables and methods.

Foreign astronomy also faced its share of resistance. In the Komnenoi period, Greek sciences were contrasted to "modern" methods, and the presence of these more recent astronomical and astrological treatises remained overall discrete. In Palaiologan times, the spread of Persian astronomy emphasized how much the Ptolemaic heritage had to be revised, yet several astronomers clung to tradition by combining these Persian methods and tables with the existing Ptolemaic material. Nonetheless, one should avoid considering this attachment as lacking any foresight or originality. Ptolemaic methods had proven their efficacy over centuries and the Persian material inherited was faulty. A range of foreign works—Arabic, Latin, Persian and Jewish—was explored, tested and compared, which in itself emphasizes how much Byzantine astronomers acknowledged the need to break from the Ptolemaic tradition. The comparative work done by some may not have been fully satisfactory, but it did make Byzantine astronomers active participants in the astronomical

157 On these texts, see Caudano, "Cosmologies et cosmographies."

158 See above, p. 210; Baudry, "Un traité cosmologique," pp. 1–32. These two ideas did not necessarily circulate together (see for instance, Kunze, "Die Anonyme Handschrift (Da 61)," p. 360).

159 Caudano, "Cosmography, Asceticism and Female Patronage."

discussions and exchanges that characterized the Eastern Mediterranean in the 15th century. Overall, the most puzzling aspect of Byzantine astronomy is probably the lack of any direct observation and the exclusively mathematical approach that characterized their work.

CHAPTER 7

# Geography

*Inmaculada Pérez Martín and Gonzalo Cruz Andreotti*

## 1 Introduction

To manage space and time and to reflect upon their nature is connatural to any human society. Views on space were as plural as the ways to perceive it and experiment with it and geography was the intellectual tool used to explain them. Even if it was never central to elite training during antiquity and the Middle Ages, the need for understanding and explaining reality, beyond the daily experience of the *oikos* or the *polis*, gave birth to geographical knowledge. Geography began with empirical experience and eventually became a conceptual and analytical tool that evolved alongside the great historical changes, producing different geographical narratives according to each cultural and ideological framework. In this process, the main Greek contribution involved the implementation of an extraordinarily abstract way of thinking, which, in its turn, created a peculiar geographical and cartographic language developed from more limited and fragmented realities.[1]

In Byzantium, geographical knowledge played a major role in the shaping of its cultural identity, since it was an essential part of a Roman past enduringly revindicated.[2] This becomes evident when, in 9th-century Constantinople and probably under the influence of the Abbasid scientific policy, the imperial power hired Leo the Mathematician (*c.* 790–after 869) to promote the study of the *Quadrivium*—a choice that eventually laid the foundation for a scientific and observational approach to the understanding of the *oikoumene*. Shortly after, the first Macedonian emperors boosted the reading of Greek history and the recovery of geographical and ethnographic data.[3] Again, this choice led

1 Prontera, "La Geografia dei greci."

2 It is interesting to point out that Strabo, the champion of the *pax romana*, did not find readers (but see below Basil of Caesarea) until the *Geography* was used in 6th-century Constantinople among others by Procopius, with the similar aim of presenting Justinian as the new forger of a pacified Empire; see Maas, "Strabo and Procopius," pp. 67–70, 75–83.

3 The earliest preserved copies of Xenophon or Plutarch date back to this moment, the end of the 9th and the beginning of the 10th centuries, while we must wait a few decades before finding the first preserved copies of Herodotus, Thucydides or Strabo. The great ethnographic compendium of Constantine Porphyrogennetos, *De Administrando Imperio*, composed in 948–952, comprises geographical excursus, for example, on the Dnieper's rapids. On the

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to the recognition of the historical space Byzantines shared with Romans and contributed to model the apparent continuity with the past that shaped their identity.[4] The most important geographical texts read and copied in Byzantium (Ptolemy and Strabo, together with Dionysius Periegetes and Pausanias) were considered the ultimate outcome of the knowledge generated by antiquity.[5]

As might be expected, the Byzantine worldview was also imbued with biblical Cosmogony. At a political level, the imperial (Constantinian and Theodosian) notion of the *oikoumene* and the *orbis terrarum* mixed and developed with the concept of God's government;[6] in this context, the Barbarian easily became the non-Christian and, just as the Romans had tried to assimilate the surrounding nations, the Church aimed at expanding Christianity beyond its imperial borders.[7] Building on this foundation, the assimilation of classical paradigms was achieved smoothly. In late antiquity, biblical cosmogony was assimilated in different ways, based on the philosophical sensibility of the writer.[8] Bible scholiasts, such as Theodore of Mopsuestia (*c.* 350–428), tried to deny the sphericity of the earth. Their failure to impose their ideas, however,

irregular focus of this work on topography and ethnic geography, see Magdalino, "Constantine VII and the Historical Geography," 34–37.

4 Good overviews on the subject, Wolska-Conus, "Geographie"; Koder, "Sopravvivenza"; Külzer, "Η γεωγραφία στο Βυζάντιο"; a concise introduction in Pérez Martín, "El libro en Bizancio, compañero de viaje," 257–262.

5 Strabo's and Ptolemy's contributions probably hindered the survival of previous authors, even those who were prestigious in their time, such as Eratosthenes or Posidonius. For instance, Stephanus of Byzantium's *Ἐθνικά*, or *Περὶ πόλεων*, a geographical dictionary compiled in alphabetical order, very rich in historical and mythological information, was only preserved through excerpts and Hermolaos' epitome, from the 6th century. The preserved copies are not Byzantine, but they were produced later in time, as it happened with the manuscripts of Pausanias' *Guide to Greece.* Cf. Bouiron, "Du texte d'origine à l'Épitomé des *Ethnika*."

6 Contemporarily, according to Traina, a basic geographical knowledge and the use of maps became popular and transformed into the overt expression of Roman power, in which the elite liked to see itself reflected. Cf. Traina, "Geografia dell'Impero," "Mapping the World under Theodosius II," "Mapping the New Empire"; on the intertwining of political geography and geographical learning, see Gautier Dalché, "L'enseignement de la géographie," 171–4, who advocates the use in a learning context of the map set up by Theodosios II in 425 near to the Capitolium where the imperial higher education was bestowed.

7 Racine, "Geography, Identity," goes beyond this notion and proves, through the convincing example of St Christopher, that the Christianization of remote people and places transformed the limits of the known world in Late Antiquity.

8 See Inglebert, *Interpretatio christiana.* On Basil of Caesarea's doctrine, Mendieta, "La préparation," pp. 353–54, and on other hexaemeral literature, Robbins, *Hexaemeral Literature*; Scholten, "Einleitung"; John Philoponus, *De opificio mundi*, vol. 1, pp. 52–62. This corpus has been explored as part of the traditional quest for lost philosophical texts, but still needs an overall assessment of the different cosmographies involved.

prevents us from equating their worldview with the Byzantine one. As shown in these pages, Byzantium was the heir to the ancient conception of the oikoumene as a part of the earth's globe, and as such, its own thoughts revolved around that conception. Our aim here is not to describe this mix of biblical tradition and scientific discussion in terms of innovation or progress, nor to characterize certain texts that offer geographical knowledge,[9] but to explore at different levels the view Byzantines had of the oikoumene.[10] By doing this, we will be able to critically assess the traditional vision of Byzantine culture as a uninterrupted connection with the past and we will explain the developing contexts of its reception of and contribution to geographical knowledge.

There are many and long-standing geographies: one measuring and explaining the inhabited world as a whole with the help of the stars; one used as an instrument of prestige and power by the military, commercial, and economic interests of the empire;[11] one defining boundaries, with a clear diplomatic value and a strong paradoxographical content, resulting from the observation of the surrounding peoples;[12] one religious, associated with ritual places and routes.[13] But it is not a matter of distinguishing which "geographies" move in or out of the classical inheritance—with Ptolemy as a reference—, but to gain a glimpse, at least, of the reasons why a certain geographical wisdom was put aside, while other traditions adapted, re-read and reinterpreted themselves.[14] On this basis, our contribution, without claiming to be exhaustive, aims at

9 The chapter by Dilke, dedicated to Byzantine cartography, in the prestigious series *The History of Cartography* (Dilke, "Cartography") focuses on the classical tradition from this continuist perspective. The entire study, basically focussed on the antagonism between Kosmas and Ptolemy, is intended to assess to what extent Byzantium assumed, or not, a substantial part of Graeco-Roman cartography. A similar outlook on the conservatism of the scarcely groundbreaking Byzantine geography may be found in Della Valle, "La cartografia bizantina." Brodersen, "Cartography," offers a critical view, different from Dilke's, on the modernist perspective of *The History of Cartography*, and Podossinov, "Karte und Text," p. 9. Cf. the approach of Koder, "Sopravvivenza," and Makris, "Geographische Kenntnisse," who refuse to speak of "regression" vis-à-vis with the past.

10 For a classification of Byzantine geography in academic, political, and popular, see Angelov, "'Asia and Europe Commonly Called East and West,'" pp. 45–52.

11 "For the most part, geography exists for the needs of states," has written Strab. 1.1.16.

12 Kaldellis, *Ethnography*; Magdalino, "Constantine VII and the Historical Geography."

13 On gardens and mountains as spiritual places in hagiographical writings, Della Dora, "Gardens of Eden." *Pilgrimage in the Byzantine Empire, 7th–15th centuries*, was the subject of the Dumbarton Oaks Symposium 2000, published in *Dumbarton Oaks Papers*, 56 (2002).

14 Jacob/Mangani, "Nuove prospettive," already called for an approach free of cultural and scientific essentialisms; cf., in full, Jacob, *L'empire des cartes*.

drawing attention to some lesser-known texts and images, which may contribute towards a more thorough knowledge of Byzantine geographies.

Although every classification is revocable, especially in a civilization such as the Byzantine one, where studies testify to very different perspectives and methods, it is useful to pay attention to what is proposed by the texts themselves:

1. What is usually taken for Byzantine geography: the cosmology or global explanation of the universe based on beliefs. In the Greek world, geography cannot be separated from philosophical tradition, and in late antiquity it took the form of commentaries on Genesis (*Hexaemera*), the first and most influential being Basil of Caesarea's *Homilies on the Hexaemeron*. Other commentaries on Genesis were lost, because of the condemnation of their authors, although at least Kosmas Indikopleustes' *Christian topography* was preserved, as well as a very interesting and more successful continuation of Basil's attempt: *De opificio mundi* by John Philoponus.
2. The physical geography, based on the Aristotelian tradition and the Stoic synthesis, which tackles the known world according to its physical elements (water courses, types of terrain and flora, tides, seasons, etc.).[15] This is probably the most common Byzantine approach to the understanding of phenomena concerning the human environment, becoming a frequent subject in popularized works, such as the question-and-answer compendia composed by Michael Psellos (1017/8–1078?) or Symeon Seth (second half of the 11th century).
3. A political and literary geography, deeply rooted in Homer, which included Strabo, Pausanias, Dionysius Periegetes, Stephanus of Byzantium, and the corpus of short archaic *peripli*.[16] In this tradition, Byzantium produced chrestomathies of Strabo, commentaries on Dionysius and short pieces, such as Michael Psellos' *On the Athenian places and names*.[17] Photios (*c*. 810/820–893) deserves a special mention since his *Myriobiblon* abridged and commented on several geographical books.[18]

15 Cf. Arist. *Meteor.* 1.13 (349b–351a), 2.5 (362a–b), but also the post-Alexandrian tradition represented by Ps.-Aristotle, *De mundo*, § 3, especially 393a–394a. See Telelis' chapter on Meteorology and Physics.

16 On the contribution of Marcianus of Heraclea to this corpus, preserved by Par. suppl. gr. 443, see Diller, *Minor Geographers*, pp. 45–47; Marcotte, *Géographes*, pp. cxx–cxxiv; Prontera, "Marciano di Eraclea," 522–23; González Ponce, *Periplógrafos*, pp. 23, 41–42.

17 The piece reworks Strabo 9, 1; see Rhoby, "Untersuchungen."

18 On Photios' contribution to our knowledge of ancient geographical texts, see Micunco, *La geografia*.

4. Finally, mathematical or astronomical geography lies the closest to the current concept of the discipline. Byzantium not only read entirely its Ptolemaic version, but knew different summaries of Posidonius' and Eratosthenes' theories by means of Strabo, Geminus, Cleomedes, or Macrobius.

Besides the oldest manuscripts of the Ptolemaic maps (and especially, the MS Vatican, Biblioteca Apostolica Vaticana, Urb. gr. 82)[19] and Strabo's oldest preserved copy (MS Paris, Bibliothèque nationale de France, gr. 1397, from the second half of the 10th century),[20] we may consider two miscellanies as the most important Byzantine codices transmitting ancient geographical wisdom. The first one is a 9th-century codex, MS Heidelberg, Universitätsbibliothek, Palat. gr. 398, which gathers, among paradoxographical collections, Strabo's *Chrestomathy* with a small group of *peripli* and *hypotyposeis* probably shaped in late antiquity and linked to the Neoplatonic school.[21] In Byzantium, these short geographical or chorographical introductions were always marginal, compared with the longer prose texts of historical geography (see below). It was their eventual compilation with other geographical texts that guaranteed their survival. This operation took place again at the end of the 13th century, when a huge parchment codex, now scattered between Mount Athos (MS Vatopedi Monastery 655, the main part of the original manuscript), London (MS British Library, Additional 19391, 21 fols.) and Paris (Bibliothèque nationale de France, suppl. gr. 443A, 7 fols.), brought together all the major and minor geographical texts then available in Constantinople.[22]

In the following pages, we do not adjust to the quadripartite scheme described above but we propose what we believe are the most interesting discussion threads on Byzantine geography (not significantly different from the debates around Greek and Roman geography), as evidenced by the study of the Byzantine, mostly Constantinopolitan, texts and manuscripts. In our case, the conclusions must be considered provisional since the field still requires a big amount of research on the largely unexplored documentation. For instance, authors such as Strabo, Dionysios Periegetes or Ptolemy require on their own a much more thorough approach than we may provide in these pages.

19 Gentile, *Scoperta*, pp. 78–80 (No. 38); Burri, *Die Geographie*, pp. 479–83.

20 Bianconi, *Cura et studio*, pp. 6–8.

21 Ronconi, *I manoscritti*, pp. 34–75; Marcotte, *Géographes*, pp. xx–xxi; id., “Le corpus géographique,” pp. 172–75; id., “Priscien de Lydie.”

22 Burri, *Die Geographie*, pp. 238–55.

## 2 The Christian Cosmography: Geography and Theology

The ideas expressed by Kosmas Indikopleustes' *Christian Topography* (written in Alexandria in the middle of the 6th century) are usually upgraded to become a paradigm of Byzantine cosmography.[23] The *Topography* was an offspring of the literal interpretation of the Bible, backed by the Antiochean school, and stood for Theodore of Mopsuestia's reading of Genesis, not in Antiochia, but in Alexandria.[24] In the Byzantine tradition, it was an eccentric contribution, isolated from the ancient, general worldview of the earth as a sphere, and never obtaining the recognition or the attention it attracts now.[25] The poor dissemination of the work (only three manuscripts from the 9th–11th centuries are preserved) helps to drastically resize its hypothetical influence, and the status it holds nowadays as paradigm of Byzantine geography. In the codex of the *Myriobiblon* dedicated by Photios to the *Christian topography*, Kosmas' views of the earth and the heaven are branded as "absurdities": "He relates much that is incredible from an historical point of view, so that he may fairly be regarded as a fabulist rather than a trustworthy authority," wrote Photios.[26] Even if the famous shape of the cosmos modelled according to Moses' tabernacle, belonging to the set of illustrations in Kosmas' manuscripts,[27] astounds us, we must admit that it was just a peculiar and isolated attempt to link cartography and creed, namely the Alexandrian and the Mosaic geographical traditions.

In Alexandria, a quick response to Kosmas' cosmology was offered by John Philoponus in his *De opificio mundi*,[28] a documented introduction to the *oikoumene* and a defense of his creation against the Aristotelian and Neoplatonic conceptions of world's eternity. As might be expected from a significant connoisseur of Aristotle's philosophy and a student of the Neoplatonic school in

23 Kosmas Indicopleustes, *Topographie Chrétienne*, ed. Wolska-Conus; Kominko, *The World of Kosmas*. On Kosmas see chapter 1 of this volume.

24 Kitamura, "Cosmas Indicopleustès," pp. 81–83, Congourdeau, "Cosmas Indicopleustès," pp. 50–66.

25 On the Byzantine tradition of the Antiochean Cosmology, Caudano, "Un univers sphérique ou voûté?," Ead., "'Le ciel a la forme d'un cube." It seems also that the *Topography* could have had some impact on the Canterbury School; see Bischoff/Lapidge, *Biblical Commentaries*.

26 Photios, *Myriobiblon*, ed. Henry, pp. 21–22 (codex 36).

27 Kominko, *The world of Kosmas*, pp. 105–32. On the influence of the *Christian topography* in the world map drawn in Bologna, Biblioteca Universitaria, 3632, see Caudano, "'These Are the Only Four Seas,'" pp. 176–80, 190.

28 Ed. Scholten, vol. 2, pp. 382–93; cf. Scholten, *Antike Naturphilosophie;* Sorabji, *Philoponus*, pp. 49, 78–81, 92–94.

Alexandria,[29] Philoponus' commentary on Genesis 1 is a fine analysis which awakened the admiration of Photios, due to its purity and clarity (codex 43). This did not prevent *De opificio mundi* from practically disappearing, since nowadays it is preserved only in a single manuscript (Wien, Österreichische Nationalbibliothek, Vindob. theol. gr. 29). Another codex of the *Myriobiblon* (codex 240) offers a summary of Philoponus' arguments on the creation of the world; they materialize another attempt to overlap biblical cosmogony with recent scientific Alexandrian acquisitions.[30] On behalf of the geographical content, Philoponus, using general data provided by Aristotle and Ptolemy, aligned with Basil of Caesarea in the defense of the sphericity of the earth against Theodore of Mopsuestia, as well as in other points in dispute.[31]

Photios pointed to the similar content *De opificio mundi* shared with a work much better known in Byzantium than Kosmas' or Philoponus' writings, Basil of Caesarea's *Homilies on the Hexaemeron* (or the six-day creation of the world according to the beginning of Genesis), written in 378.[32] Basil's geographical notions concentrate on *Hom.* 3 and 4, and more specifically on the paragraphs devoted to the distribution of water and dry land throughout the earth's surface (*Hom.* 3.6, 4.2–4). This topic involved discussion about tide levels, underground currents and the volume of seawater, as well as on the central issue of the Ocean's edges. Discussion also took place as to whether the Caspian and Hyrcanian Seas were gulfs or closed basins (*Hom.* 4.4, p. 63.11–15) and the difference of level between the Mediterranean and the Red Sea (*Hom.* 4.3).[33]

These remarks are specifically mentioned as arising from the contemplation and admiration of the divine creation (*Hom.* 4.1), although Basil's perception was evidently biased by his classical background. In the past, his sources have been the subject of lively debate, since the issue at stake was the fragmentary remains of thinkers such as Posidonius, Ephorus, or Eudoxus.[34] It is likely that

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29 He was a disciple of Ammonius and wrote several Aristotelian commentaries: this commentary on *Meteorologica* is partially preserved and the remaining fragments do not deal with any geographical issue.

30 Schamp, "Photios et Jean Philopon," p. 136.

31 Congourdeau, "Cosmas Indicopleustès," pp. 153–57.

32 It enjoyed widespread dissemination in view of its extant Byzantine copies and, from an early date, versions in other languages: Basilius Caesariensis, *Homilien zum Hexaemeron*, ed. Mendieta/Rudberg.

33 This discussion went on relentlessly from Herodotus (1.203) onwards; see Janni, "The Sea of the Greeks and Romans," pp. 28–30; Gehrke, "The 'Revolution' of Alexander the Great," pp. 85–87.

34 On Basil's sources, Mendieta, "La préparation," pp. 360–67. On his dependence on the Aristotelian tradition in Physics and Natural Sciences, see Müllenhoff, "Aristoteles bei Basilius von Caesarea" and Sorof, *De Aristotelis geographia*.

much of the literature available to Basil no longer exists and that he used compendia such as the epitome of Posidonius' *Commentary* preserved in a papyrus.[35] The bishop may also have read Strabo[36] and he mentions the testimony of the "geographies of the authors that narrated (those facts)" (ταῖς τῶν ἱστορησάντων προσέχειν γεωγραφίαις), suggesting that he had access to some geographical accounts on the edges of the *oikoumene* that could be part of the Alexandrian propaganda.[37]

Unlike the much discussed sources of the *Hexaemeron*, this tradition in Byzantium still awaits study.[38] The approach to Genesis undertaken by Basil constituted a first, influential, although not entirely consistent, attempt.[39] The next work was Philoponus' *De opificio mundi*, which provided in chapter 4.5 a balanced and well-structured answer to the question "How one sea may be many seas at the same time?"[40] The section contains a panoramic view of the Inner and Outer Seas,[41] which leads him to deal with the Torrid zone, the Nile's course, and the lack of differentiation among seas. Philoponus knew Basil's *Hexaemeron*, even if he did not follow it and paid more attention to the texts of Aristotle, Ptolemy and other Alexandrian mathematicians he had at hand. Indeed, the issue dates back to the 6th century BCE, when the first geographers outlined the Ocean as a circle around the Earth, starting with Hecateus and Herodotus (4.36.2).

35 See Lasserre, "Abrégé inédit."

36 Even if Basil never followed Strabo's wording, he mentioned the Western Sea's tides (*Hom.* 6.11, p. 108.19–22, but not Pytheas) and the lakes Asphaltitis and Serbonitis (*Hom.* 4.4, p. 63.7–9); cf. Strab. 7.5.8 and 16.2.42–43. Strabo has been proposed as a source for a passage in *Hom.* 4.4 (p. 63.11–15) by Cataudella, "Geografia e propaganda."

37 Authors such as Arrianus pushed eastwards the Asiatic adventures of Alexander by modifying the names of seas and rivers. This is the tradition Basil follows when he introduces the Caspian and Hyrcanian seas as gulfs; see Cataudella, "Alessandro Magno," and Id., "Geografia e propaganda," 13. Cf. Gómez Espelosín, "La imaginación geográfica." This precise misunderstanding was also pointed out in Strabo by Georges Gemistos Pletho, who wrote a *Correction of some mistakes made by Strabo* (ed. Diller, "A Geographical Treatise") in Strab. 2.118–131.

38 Some hints in Nicolaidis, *Science and Eastern Orthodoxy*, pp. 17, 102–3. The last link in the chain is Palamas' *Kephalaia*, § 9–14, with cosmological content (pp. 92–99 ed. Sinkewicz).

39 Adressing these homilies to a mixed audience was the alibi given by Gregory of Nissa for the inconsistencies reported by cultivated contemporaries; cf. DeMarco, "The presentation," p. 333; on Basil's intellectual acrobatics in order to respect the literal interpretation of the Bible, Mendieta, "La préparation," pp. 352–54.

40 The question is asked at the beginning of chapter 4.5, but the title ("That the Ocean does not embrace the entire earth nor connects with the Red Sea, but there are more water systems") contradicts Philoponus' statements and was probably added later in time.

41 See ed. Scholten, vol. 2, p. 384, n. 13.

In contrast, and contemporary to Philoponus, although in Constantinople, Ps.-Kaisarios' *Erotapokriseis* § 79–81[42] offered an abridged rephrasing of Bas. *Hom*. 4.3–4 that involved the spreading of the *Hexaemeron* in monastic circles. Ps.-Kaisarios' text is so close to the source, that not only the answers, but also the questions, are taken from Basil's homilies.[43] However, this is an isolated case; other examples of the genre of the *erotapokriseis* or *kephalaia*, despite being central to the understanding of the "popularization of science" in Byzantium, did not hold a prominent place in the dissemination of geographical knowledge. Even when dealing with the creation of the world, they rarely went into sufficient detail concerning the description of the *oikoumene*.

The opposite situation is found in two collections from the late Macedonian period, using the same format, yet embedded in the Aristotelian tradition regarding the nature and the *oikoumene*'s place in the cosmos. Michael Psellos' *De omnifaria doctrina*, a doxographical collection of theological and philosophical common notions, written in very simple language, included a few paragraphs *On winds* (§ 146), *On the earth's tilt* (§ 160), *On what right and left are* (§ 162), as well as on some harbours, rivers, and the flooding of the Nile (§ 174–177).[44] The 150 manuscripts preserving this question-and-answer collection testify to its success and suggest the widest dissemination of a tradition. Its content does not stand up to a scholar such as Psellos, but it helps us to frame this wisdom within a philosophical context. Indeed, the only chapter dealing with the creation (§ 157) leads him to point out the differences between Aristotle, Plato, and Christian thought; in the same mode, when he writes back to John Xiphilinos to continue a discussion on ancient philosophy, Psellos mentions the fact that geography had already been a topic of debate between them,

> although shortly before you did not know that the South and not Asia is in front of the Ursa major, or that we say the Europeans live further north than the Africans; but now if this geographical wisdom makes you attack me, separate the climatic zones as you want. For I did not write you my previous letter with the purpose of dealing with geography or dividing the entire earth, but in order to prove your unyielding determination to hide any sign of feebleness.[45]

42 Ed. Riedinger, pp. 64–65.

43 On Ps.-Kaisarios' use of Basil's homilies, see Papadogiannakis, "Encyclopedism," p. 35.

44 Ed. Westerink. See Hunger, *Die hochsprachliche profane Literatur*, vol. 1, p. 522.

45 Psellos, *Epistle to John Xiphilinos*, § 5, ed. Criscuolo, pp. 53–54 (ll. 138–146).

The magistros Symeon Seth, perhaps a Psellos' disciple, dedicated his *Physical synopsis* to an unknown emperor.[46] The abstract of book 1, "*On the earth and the oikoumene*," devoted to the description of the basic principles of the human environment, reads as follows: "On the earth, that has a spherical shape and is in the middle of everything; how many stadiums has its perimeter; how much and which part of it do the human beings occupy; how the seven climates are distributed; how far eastwards do the human beings live, and which is the western limit of their dwelling, and which is the northern, and the southern."[47] Book 1 offers indeed in its few pages a clear and elementary presentation of some geographical notions rooted in antiquity, which are completely foreign to biblical cosmology. The simple syntax and vocabulary ease the reading of the text; the subjects are presented in short chapters; and these choices made by Seth explain the success of the *Synopsis*, very often copied from the 13th century onwards.

## 3 The Teaching of Geography: Texts and Images[48]

Basil's *Homilies* as well as Psellos' and Seth's collections may have supplied Byzantine minds with some information on rivers, lakes and seas. However, the average schooled Byzantine also had access to a compendium of Roman geographical knowledge, Dionysius Periegetes' *Description of the Known World*, a brief encyclopedia in 1,187 verses.[49] In Byzantium, the *Periegesis* probably became the most popular text to provide a succinct description of the *oikoumene*, thanks to the prestigious patina granted by Homer and to the mnemonic

46 Symeon Seth, *Σύνοψις τῶν φυσικῶν*, ed. Delatte, *Anecdota Atheniensia*, vol. 2, pp. 17–89. This is its table of contents: logos 1: the earth and the *oikoumene*; logos 2: the elements between the earth and the sky; logos 3: the sky and the stars; logos 4: the matter, the form, the nature, the soul and spirit; logos 5: the first cause and the providence.

47 Symeon Seth, *Σύνοψις τῶν φυσικῶν*, p. 18.

48 Dalché, "De la glose a la contemplation," is an outstanding study on the connection of maps with adjacent texts in Latin manuscripts. Not only does it shed light on the different types of illustrations (basically diagrams and maps, with various combinations), but it also explains their place in the codex and their connection to referential texts (inside and outside the figures), establishing whether the images were created or added by the writer or by the reader. The result is somewhat heterogeneous and resists classification. Nevertheless, the many examples provided prove that the image, even if it is connected to the text, can also become on its own a powerful vehicle for the transmission of knowledge and ideology. What follows is only meant to be a first approach to the Greek transmission from this perspective.

49 Dionysius Periegetes, *Description of the Known World*, ed. Lightfoot.

usefulness of its lines.[50] Dionysius was not a traveller or an astronomer, but his schoolbook of geography succeeded in giving a clear, coherent and organized picture of the world and in providing the Roman citizen with a global framework or mental representation of unseen regions and peoples.[51] The *Prolegomena* and scholia to the poem preserved by many codices still need to be studied, although it is evident that Byzantines learned from this poem geographical data, as well as ethnographical and mythological-historical information. For that matter, the *Periegesis* was usually copied along with other texts in verse such as Aratos or Hesiod and the accordingly shaped miscellanies prove that Dionysius' work survived by being read in educational contexts.[52] In the West as well as in the East, the key to its success lies in the mixing of geographical, cartographical/figurative, mythical and literary notions organized according to a general picture and to lists of places that eventually demand to be read and studied along with a map.[53]

Eustathius of Thessalonike (*c*. 1115–1195/6) wrote a commentary on the *Periegesis* when he was *maistor ton rhetoron* in Constantinople in 1168–78, before undertaking the commentaries on the Homeric poems.[54] His purpose was allegedly not to correct or to supplement Dionysius' words, but to paraphrase and amplify them with historical and geographical information.[55] In order to do so, he used extensively Herodotus and Strabo, who in a sense wrote in the wake of Homeric geography, a field Eustathius was comfortable with, although

50 On the ancient mnemotechnical procedures, see Lazaris, *Art et science vétérinaire*, pp. 98–103; on didactic poetry, see chapter 2 of this volume.

51 On the *Periegesis* see Ilyushechkina, *Studien zu Dionysios von Alexandria*; as a window to the mental image of the world, see Jacob/Detienne, *La description de la terre habitée*, pp. 28–35. Like Strabo (see below), Dionysius turns to geometrical *schemata* or familiar objects in order to visualize a space; see Fig. 7.1.

52 On miscellanies including the *Periegesis*, Reeve, "Dionysius the Periegete." According to Aujac, *La Sphère*, pp. 66–68, Aratos' *Phaenomena* influenced Dionysius, who aspired to do with geography and the map what Aratos had made with astronomy and the celestial sphere. On the complementarity of Aratos and Dionysius, see below. On the Periegetes' transmission, Tsavari, *Histoire du texte;* Marcotte, "La Periegesi."

53 On Dionysios' map, Jacob, "L'œil et la mémoire," pp. 38–42. We make our own the words of Gautier Dalché "L'enseignement de la géographie," 163: "Il n'est pas question d'entrer ici dans le débat sur l'existence ou l'absence de cartes dans l'Antiquité, largement biaisé par des interprétations personnelles ou des a priori sur ce qu'est ou devrait être une 'carte,' la conclusion négative ignorant totalement de nombreuses références dans la littérature antique." On the distinction between "scientific map" and "figurative map," running parallel throughout Antiquity, see Prontera, "Carta e testo nella geografia antica."

54 On Eustathios, Pontani/Katsaros/Sarris, *Reading Eustathios*. On the *Commentary*, Cassella, "Sul commentario di Eustazio"; Pérez Martín, "Geography at School." The text was edited by Müller, *Geographi Graeci minores*, vol. 2, pp. 201–407.

55 Ed. Müller, pp. 205–6.

he also read Ptolemy, Aratos, and doubtless other texts. Dionysius' lines inspired Eustathius' reflections and erudition on the inhabited space, as did the introductory epistle addressed to John Doukas Kamateros,[56] which allowed him to establish a general framework and some notions on the representation of the *oikoumene* from Anaximander onwards: the definition of topography, chorography, *periodos ges* and periegesis, and the political and historical value of geography. In order to accomplish all this, he used the introductory books of Strabo and Ptolemy.[57]

In this epistle, Eustathius states: "They certainly have done this [*sc.* to circumscribe what lies under the skies] in a small space, those who have dealt with the map (*pinakographia*) of the *oikoumene*, when they enclosed infinity in something as small as a nail and they circumscribed the boundless totality of the earth to a surface of minimal dimensions. It is said that the first to do so was Anaximander, disciple of Thales, and after him, Hecataeus also dedicated himself to the same task, and after him, Democritus, and in the fourth place, Eudoxus" (translated from ed. Müller, p. 208.9–17).

Other testimonies prove that it is not through the reading of Strabo that Eustathius became familiarized with the use of maps, but that these small-scale representations formed an integral part of his reality.[58]

Strictly contemporary with Eustathius, the possessor of the MS Milano, Biblioteca Ambrosiana, C 222 inf. thought it was worth transcribing the following conversation with the rhetor John Kamateros in a brief note on fol. 339:

> According to Kamateros' words, of all the poetical books, two poets need to be sensed and kept in a book: the Periegetes and Aratos, for the former has described the map and the latter the sphere. Without them, the young man trying to decipher the texts would not understand anything: the map does not go without the text, so that the beholder has a sense of what is written and understands it; and the same is true for the sphere. But Aratos is the most difficult of both, as the rhetor told me.[59]

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56 John Doukas was the eparch of the City; see Stone, "The Grand Hetaireiarch," p. 146, who does not mention the testimony of this epistle.

57 Ed. Müller, pp. 207–16.

58 The scholia of Dionysius Periegetes also mention maps where certain places or geographical features are missing; cf. Müller, *Geographi Graeci*, vol. 2, p. xxiv.

59 Ed. Mazzucchi, "Ambrosianus C 222 inf.," 421: ὡς εἶπεν ὁ Καματηρὸς ὅτι ἀπὸ τῶν ὅλων ποιητικῶν βιβλίων, δύο ποιηταὶ εἰσὶ τὰ δεόμενα καὶ αἰσθήσεως, καὶ βιβλίου· ὅ, τε Περιηγητὴς καὶ ὁ Ἄρατος· ὁ μὲν γὰρ ἔχει τὸ χαρτίον ἱστορημένον, ὁ δὲ τὴν σφαῖραν· καὶ ἄνευ τούτων, οὐκ ἂν νοήσῃ τί, ὁ ἑρμηνευόμενος ταῦτα νέος· μόνον τὸ γράμμα νοήσῃ ἔχει· οὐδὲ χαρτίον ἄνευ λόγου δίδοται, ἵνα βλέπει ταῦτα τὰ γραφόμενα αἰσθητῶς· καὶ νοήσῃ αὐτά· ὡσαύτως καὶ τῆς σφαίρας· ἔστι δὲ δυσκολώτερος τῶν δύο ὁ Ἄρατος· ὡς εἶπε μοι τοῦτο ὁ ῥήτωρ:– A brief treatise from the

Michael Psellos, who became ὕπατος τῶν φιλοσόφων and taught a great variety of philosophical subjects in Constantinople from 1047, wrote a *Περὶ τοῦ γεωγραφικοῦ πίνακος*, explaining how to draw a map of the *oikoumene*. With this in mind, he positioned important places, using cardinal points or providing locations by relating them to others—a very traditional practice in geography. Although the treatise is an epitome of Strabo, it must be understood as a secondary product, of purely academic dissemination, proving that Psellos taught geography to his students by using maps.[60] This is confirmed by his *Encomium in matrem*, vv. 1911–13: "I thus need to explain to them [*sc.* disciples who often come and ask him about various disciplines] all geography, and correct or integrate for them what is lacking in the geographical map."[61] Maximos Planudes' (*c.* 1255–1305) *ep.* 86 mentions a γεωγραφικὸν πινάκιον showing Thessalonike, while Gregory of Bulgaria's (1313/4–1327) *ep.* 3 speaks about a map (γεωγραφίας πινάκιον) showing the position of Trebizond.[62]

The topic comparing the immensity of the universe with its small representations, already found in Eustathius, appears once again in the encomium of Manuel Holobolos (fl. 1261/2–1296/1310) to Michael VIII, written after the recovery of Constantinople in 1261 (or. 1). Regarding the difference between the praise itself and the object of praise, i.e., between the modesty of the written work and the greatness of the subject (in this case, the emperor), Holobolos states:

> For the sky is certainly great and high and, even when students make it spin around a sphere,[63] using a delicate, wicker structure, thus making it turn as light as a bird, this does not mean it is small; in the same manner, the earth is wide and spacious, and even when those who ponder the books of geographers and *periegetai*, inscribe it in a parchment of scant dimensions, this does not mean it is narrow. Is the sun great? And yet, the scribes compress it into a pyramidal drawing, which can easily be turned, and this does not mean it is small.[64]

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7th c., Leontius, *De sphaerae Arateae constructione*, ed. Maass, proves that the sphere was considered a necessary complement to the reading of Aratos.

60 Lasserre, "Étude," pp. 76–9, publishes it without any comment; cf. Diller, *The Textual Tradition*, p. 84; Koder, "Sopravivvenza," p. 58. A new critical edition (based on all the manuscripts) and translation in Pérez Martín, "Miguel Pselo, *Sobre el mapa*."

61 See Pontani, "The world," p. 181 (his translation).

62 Both texts pointed out by Pontani, "The world," p. 182.

63 It is doubtless an armillary sphere. On its use in ancient and medieval times, Aujac, *La Sphère*, p. 19 and Arnaud, *La cartographie à Rome*, vol. 1, pp. 192–204.

64 *Manuelis Holoboli Orationes*, pp. 49–50 Treu. Cf. Strabo 2.5.10, where he describes, on the other hand, how a sphere "at least ten feet in diameter" is needed in order to locate with

The passage suggests that, in the different contexts implied by these words (educational, learned and cultivated), the use of objects of geographical nature (spheres or maps), whether constructed or drawn, were commonplace. From a conceptual point of view, these texts demonstrate the acceptance of the sphere or the map as devices which simplify and reproduce reality, and therefore, validate the admission of visual language as a form of communication alongside writing, as explicitly pointed out by Holobolos. This would explain the circumstance suggested here: that in the students' hands, text and map could be exchangeable.

A similar educational context is expressed in the scene relative to the Socratic school in the *Clouds* of Aristophanes (vv. 200–21), represented in 423 BCE. Here, the use of the sphere, a map (γῆς περίοδος, v. 206) and instruments of calculation and measurement are shown, although it also clearly contrasts with the hodological and routine perception of space held by most citizens, who did not recognize anything in them.[65] Aristotle takes on its educational role when, in book 1, 349b of *Meteorologica*, at the beginning of his short "cartographical description," he points out that the largest rivers flow from the biggest mountains (and vice versa) and that this is obvious for people beholding (θεωμένοις) the maps (γῆς περιόδους) that were outlined (ἀνέγραψαν) from the testimonies of other individuals or from the personal observation.[66]

Two texts of Plutarch on the dispute between Nicias and Alcibiades in the Assembly of 415 BCE regarding the invasion of Sicily, highlight how young and old Athenians met at their schools and places of leisure, before taking a decision, in order to draw maps of Sicily and study the plans of its ports and navigation charts.[67] It is possible that Plutarch was extrapolating Roman reality of the 1st century CE, since Roman evidence is clearer. For instance, in 296–297, Eumenius, *magister equitum* at the court of Maximian (286–305 and 307–308) who later taught rhetoric in Augustodunum, supplicated the governor for the restoration of the ruined school and highlighted the educational virtues of a

any clarity significant parts of the map of the *oikoumene*, an experiment performed by Crates (frg. 6 Mette); in any case, the map, in order to be synoptic, while still having chorographic precision, must not be less than seven feet. For these reservations in Strabo (2.5.10; cf. 2.5.1 y 2.5.16) or Ptolemy (1.20.1), concerning the possibilities of moulding the terrestrial globe and the details of the map of the *oikoumene* into a single figure, vid. Arnaud, *ibidem*, who does not doubt the widespread use of models of celestial and terrestrial spheres.

65 Dan et al., "Common Sense Geography," 571–4.

66 Gehrke, "The 'Revolution' of Alexander the Great," 84–6.

67 Plutarch, *Parallel Lives, Nic.* 12.1 (and cf. *Alc.* 17.3–4).

map reproduced on one of its walls.[68] The process may be defined as a "democratization" of education in geography, taking place during the imperial period, when the subject ceased to circulate only among specialists. Nevertheless, this text evidences for a monumental cartography, which reminds of Agrippa's map on the Vipsana Portico[69] or that of Theodosius II near to the Capitolium.[70]

The educational use of geography, and therefore of cartography, even when not a formal discipline in the school training (despite Strabo's efforts of comparing it to Philosophy), must have become widespread during the Roman period.[71] The understanding of the new, universal and ecumenical dimension of historical space is inconceivable without prior instruction in the geographical and mathematical astronomy acclaimed by Strabo (1.1.21; 2.5.1).[72] It is true that in antiquity there is no evidence of the combination of text and map in the same document.[73] Textual descriptions frequently used a visual reference system based on analogy. For example, Iberia was compared to a bull skin; the Peloponnese to a chestnut leaf or to a mulberry tree (eventually naming the Peninsula "Morea"); the *oikoumene* to a *chlamys*, etc.[74] These analogies may also evoke, rather than represent, a geometric figure (a diamond shape, a paral-

68 *Eumenii Oratio pro restaurandis scolis*, xx-xxi, ed. AE. Baehrens, *XII Panegyrici Latini*, Lipsiae 1874, pp. 130–31: "Further, in its porticoes let the young men see and contemplate daily every land and all the seas and whatever cities, peoples, nations the unconquered rulers restore by affection or conquer by valour or restrain by fear. Since for the purpose of instructing the youth, to have them learn more clearly with their eyes what they comprehend less readily by their ears, there are pictured in that place, as I believe you have seen yourself, the sites of all locations with their names, their extent, and the distances between them, the sources and terminations of all the rivers, the curves of all the shores, and the Ocean, both where its circuit girds the earth and where its pressure breaks into it" (transl. Nixon/Rodgers 1994).

69 Plin., *Nat.* 3.17; *Dicuili Liber de mensura orbis terrae*, ed. J.J. Tierney, Dublin 1967; see Arnaud, "Marcus Vipsanius Agrippa."

70 Traina, "Mapping the World under Theodosius II"; Wolska-Conus, "Deux contributions," 274–9.

71 On geographical learning in late antiquity, see Racine, *Literary Geography*; Gautier Dalché, "L'enseignement de la géographie"; Clausi, "Scuola e geografia nella tarda antichità."

72 This is not to say that every geographical description was necessarily accompanied by a cartographic image or that the authors had in mind an Alexandrian type of "map"; in fact, many works assumed a descriptive model or point of view, based on often a hodological itinerary, as expressed by Janni, *La Mappa e il Periplo*. Cf. extensively Prontera, "Carta e testo nella geografia antica" and Arnaud, *La cartographie à Rome*, vol. 1, pp. 218–33, and below what is said about the *Tabula Peutingeriana*.

73 The exception would be the papyrus of Artemidorus, but there are serious doubts as to its authenticity; Marcotte, "Le papyrus d'Artémidore."

74 Bertrand, "De l'emploi des métaphores descriptives"; Angelov, "'Asia and Europe Commonly Called East and West,'" p. 49; Dueck, "The Parallelogram and the Pinecone."

lelogram, etc.), which does come closer to the proceedings of an Alexandrian cartographer.[75] In any case, for elite circles, it is possible to assume different degrees of cartographic knowledge and the handling of maps, varying in complexity and regularity. Undoubtedly, in the Roman period the boundaries between scientific work and the curiosity of a learned man were extremely porous: there was a continuous transfer between them, as evidenced by Cicero when he manifests the desire to write a geography in the wake of Eratosthenes (cf. Cicero, *Ad Att.*, 2.4; 2.6; 2.7). This transfer took place either through nonspecialized texts, such as encyclopedias and rudimentary reference works, or through more elaborate texts with a solid Graeco-Roman philosophical and scientific base—a tendency that would have continued up to the Middle Ages.[76]

This is the context in which a multiplication of drawings, diagrams, sketches, and maps accompanied the text in Byzantine manuscripts. Regardless of the meaning each one held, they testify to an indisputable relation between image and text, in which the former may even take precedence over the latter. Just to mention a few examples, some Palaiologan manuscripts of Oppian's *Halieutica* illustrate the migration routes of fish with diagrammatic maps focussed on the Bosphorus or Sicily.[77] In a manuscript of Dionysius Periegetes the Cyclades are represented by eleven circles encircling Delos (Fig. 7.1). In a manuscript from the 14th century with medical and astrological opuscula, a unique map of Cyprus has been recently discovered: it carefully records the outline of the island as well as its populations.[78] In Strabo's manuscripts it is not uncommon to find geometrical figures, ranging from the most simple square or rhombus with cardinal points (Fig. 7.2), to more elaborate images

75 The most significant example is Strabo. In the first two books of the *Geography*, where he revised Eratosthenes' and all of his succesors' canon, he necessarily leads us to a map—which he helps to elaborate: 2.5.13; 2.5.14; 2.5.16; 2.5.34, whilst acknowledging the practical difficulties (Strab. 2.5.10). Likewise, in Strabo's chorographic or regional books the image is dispensable and easily conceivable (cf. more recently Moret, "Strabo. From maps to words," 178–91, with nuances, Biffi "'È simile a…' L'uso delle immagini" and Prontera, "Da Strabone a Tolomeo: cartografia generale e regionale," 84–7). Neither does Polybius' map of the *oikoumene* (cf. 3.36–38) look much like an Alexandrian map; it reminds more of the *archaioi pinakes* (cf. Prontera, "Carta e testo nella geografia antica," 81–87).

76 Obrist, *La cosmologie médiévale*, pp. 27–31; Gautier Dalché, "L'héritage antique"; Prontera, "Materiali di reimpiego."

77 Marcotte, "Une carte inédite"; Cariou, "La géographie en marge."

78 Cronier/Gautier Dalché, "A Map of Cyprus."

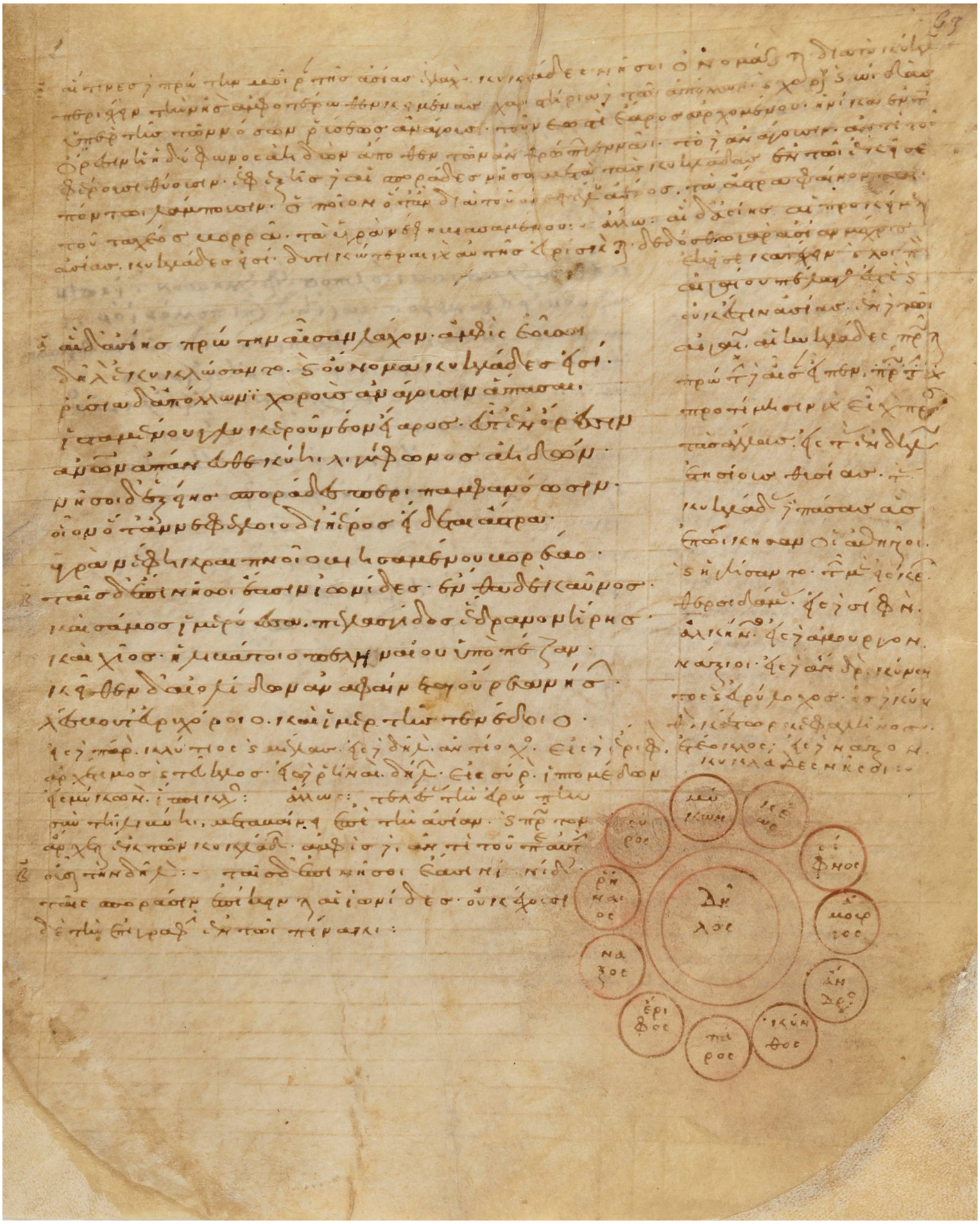


FIGURE 7.1 Cyclades Islands around Delos

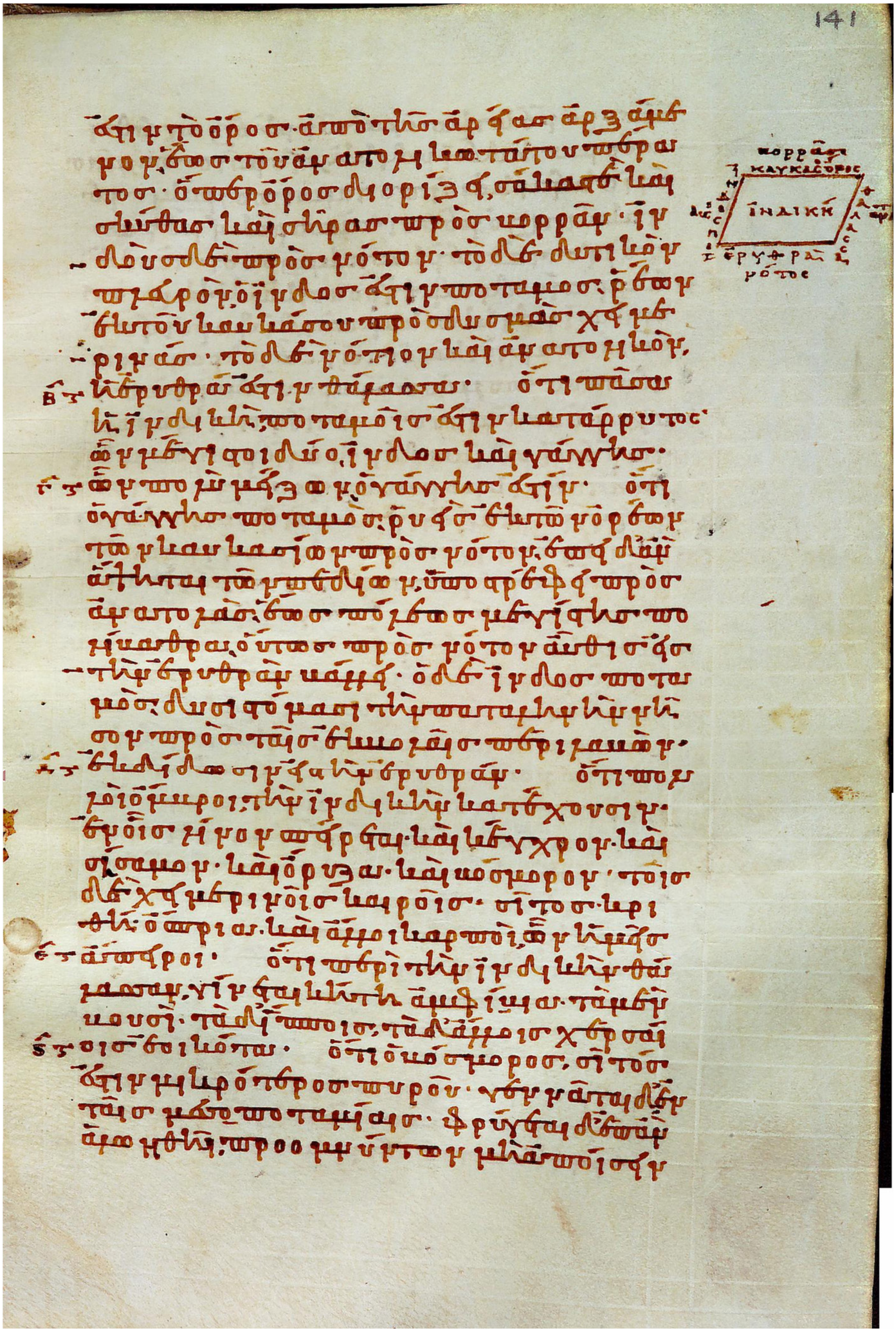



FIGURE 7.2 Eratosthenes' first *sphragis* (India)

where the geographical features are indicated by different kinds of lines.[79] The text suggests, here and elsewhere, graphic representations.[80]

A manuscript with Aristotle's *Meteorologica*, preserved at the University of Salamanca (Biblioteca de la Universidad, ms. 2747), shows a special set of figures: a wind rose, the distribution of mountains and rivers flowing from them, and the earth divided into climates and surrounded by the name of the winds in the corresponding places.[81] These schemata are not always based on *Meteorologica*, the adjacent text; rather, the illustrator has used the information provided by other texts in order to design the figures.[82]

One final point: Macrobius' *Commentary on the Dream of Scipio*, translated by Maximos Planudes at the end of the 13th century (see below), was illustrated with five diagrams to which the text specifically refers.[83] The Greek version reproduces all of them except for the fifth, the representation of the Θ-shaped earth, with the double Ocean separating the four quarters (and the inhabited one in the shape of the Strabonian *chlamys*), according to Crates' theory. It appears intentional for the Planudean version to omit the diagram of the Θ-shaped earth[84] and, in some copies, the figure (that eventually will become the archetype of medieval mappaemundi) is even substituted by another sphere incorporating the width of each zone in stadia (Fig. 7.3). Therefore we may conclude that Planudes, whilst respecting the Latin text, exercised a silent criticism of Macrobius by deleting his sketch.[85] If our interpretation is correct, the image introduced in the Greek version challenges what Byzantines

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79 Curiously enough, those figures appear mainly in the margins of Strabo's *Chrestomathy*, in manuscripts such as the MS Palat. Heidelb. gr. 398 (5 figures, see p. 252) or Paris, Bibliothèque nationale de France, gr. 571 (2 figures); on this MS, see Marcotte, "Orbis triquadrus, monde triparti," pp. 278–79.

80 Strab. *Chr.* XV 1, p. 328 Radt: ὅτι ἡ Ἰνδικὴ σχῆμα ἔχει ῥομβοειδές, cf. Strab. 15.1.11.

81 Graux/Martin, "Figures"; Harlfinger, *Die Wiedergeburt*, pp. 31–43. The 15th-century manuscript Moscow, Gosudarstvennyj Istoričeskij Musej, Sinod. gr. 415 (Vlad. 509), fol. 77v displays a very similar figure of the earth's rivers and mountains; see Podossinov, "Karte und Text," pp. 16–17, with reference to his previous publication in Russian, and a picture of the map. The Moscow manuscripts has on fols. 76v–77r a sketch or outline of the *oikoumene* that Ivanov, "An anonymous Byzantine geographical treatise," dates from 1360–90.

82 Graux/Martin, "Figures," 7–8.

83 On the diagrams of the Latin manuscripts of Macrobius, Gautier Dalché, "De la glose a la contemplation," 713–22.

84 Ed. Armisen-Marchetti, vol. 2, Annexes, Schéma 3; cf. Stahl, "Astronomy and Geography," pp. 254–58.

85 Likewise, in a few marginal notes, Planudes denied some statements on the diameter of the Sun, the Egyptian waterclocks, and the combination of similar materials; cf. ed. Megas, pp. 193–95, sch. 47, 50 and 52.

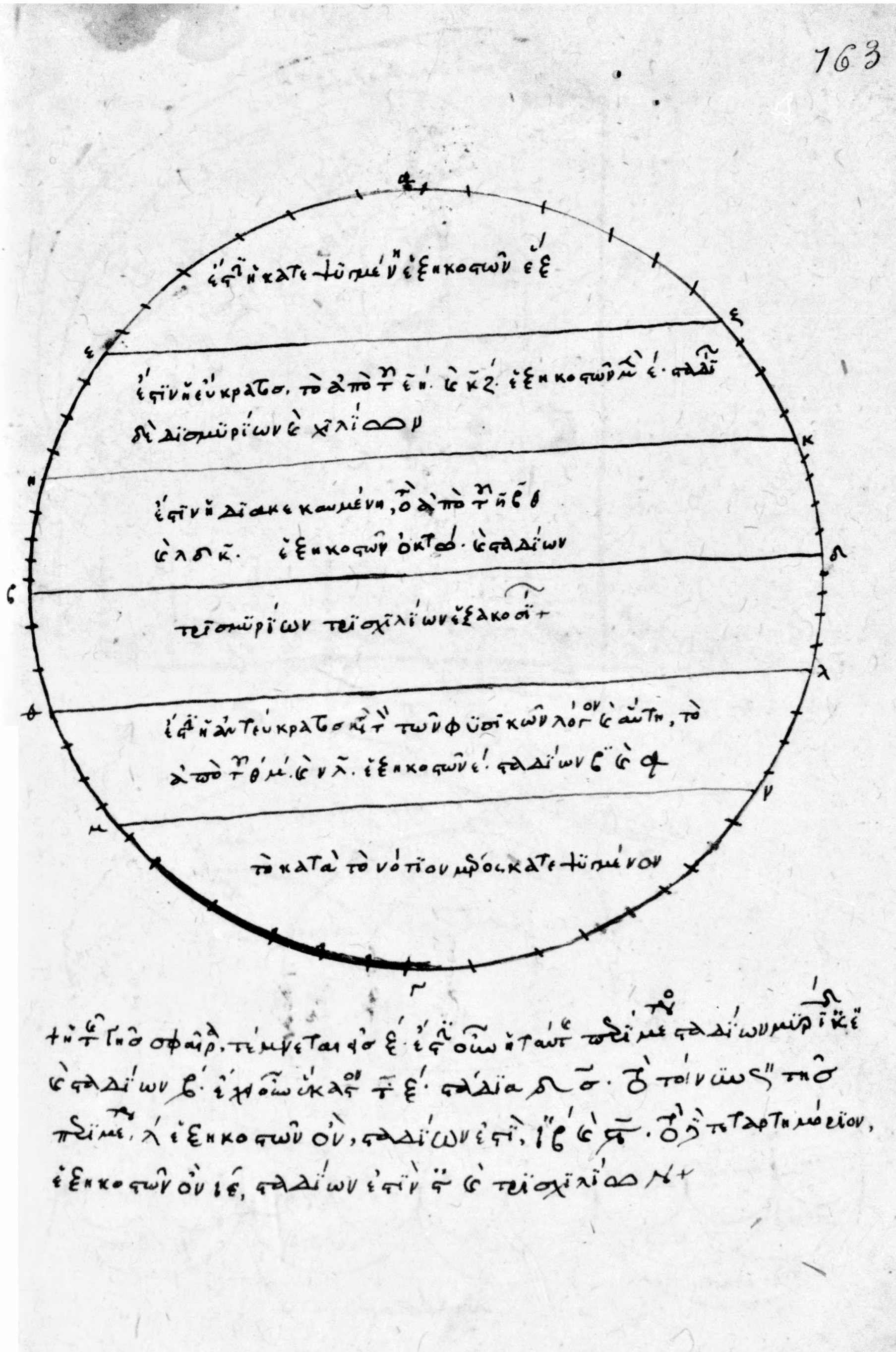


FIGURE 7.3 Earth's zones or *klimata* figure in Planudes' translation of Macrobius' *Commentary*

considered to be a wrong perception of the general framework of the inhabited world.

## 4 *Itineraria* and *Peripli*: the Geographical Knowledge Applied to Warfare and Navigation

Even if applied geographical knowledge lay outside the limits of proper science, it is worth mentioning the scarce pieces of information preserved on how Byzantine used some guides to navigate the Mediterranean. In ancient times, maritime *peripli* reflected the unidimensional and hodological concept of space that typified navigational practice. The narrative genre of *peripli*, which usually took the form of short poems, was marked by the following of a coastal route and the different topographical features encountered, as well as by time expressed in the number of days for a journey. A great number of works were composed using this model, both in verse and prose, transferring relatively verifiable information of a diverse nature, which was not always geographical.[86]

To a certain extent, this itinerary form is present in the only ancient "map" preserved in its entirety, the *Tabula Peutingeriana*, a copy from the late-12th/early-13th century of a "world map itinerary"—paraphrasing Miller.[87] This was first elaborated in the later imperial period and adapted during the Carolingian period.[88] Monumental in character (m 6.75 × 0.34 in 12 parchment sheets), it assumes an itinerary perspective in which the accumulation of textual and ideographic information, following main routes and secondary ways, is so overwhelming that it notably skews the image of *oikoumene*. This contrasts with the harmonious synthesis of the whole, which in a single view can

86 González Ponce, *Periplógrafos;* Marcotte, *Géographes*; Prontera, "Períploi." On the oral transfer of knowledge on sailing and harbour maneuvers, see Kowalski, *Navigation et géographie*, pp. 27–30.

87 Miller, *Die Weltkarte des Castorius*, pp. 48–56 and 75–83.

88 Prontera (ed.), *Tabula Peutingeriana*; Rathmann, "The Tabula Peutingeriana"; Talbert, *Rome's world*; Salway, "The Nature and Genesis of the Peutinger Map." For the Roman foundations of the Carolingian imperial ideology, cf. Lozovsky, "Maps and Panegyrics," pp. 174–76. The hypothesis considering the Tabula as a Carolingian product recently formulated by Albu, "Rethinking the Peutinger Map," 111–9, has not found consensus; for her (Ead., *The medieval Peutinger map*), the Roman idea of universal space, power, and authority of the model lingers in the claim of the Carolingian *imperium* and *romanitas*, in contrast to the idea of divine and timeless order and space displayed by the ecclesiastical circular maps. A digital reproduction of the *Tabula* is available online: <http://data.onb.ac.at/rec/AC13945113>.



FIGURE 7.4 Strabo, *Chrestomathy*, 5.9–13; Central Italy's *itinerarium*

summarize the form and extension of the *oikoumene*, which is the real added value of the map (as concisely defined by Strab. 2.5.11). Designed to be viewed as a journey with all the enjoyment of the details of the numerous roads, *ciuitates* and *mansiones* mentioned, the *Tabula* cannot constitute the paradigm of ancient cartography, from an Alexandrian perspective, nor can it be considered a practical "travel guide," but rather as an example of the hodological perception of space in which detail overrides any possibility of understanding the whole. Pictorially it exalts the "real" extension of the Roman dominion of the world, representing in a single *volumen* or scroll an enormous mass of information (not always updated or coherent), which would be very difficult to find in a "Greek" ecumenical map. This is a considerable innovation that abandons, therefore, the harmony of shape in favour of content.[89]

The already cited MS Palat. Heidelb. gr. 398, preserves on fol. 77 (lower margin), a representation of Central Italy (Τυρρηνικὴ χώρα καὶ Τουσκία), illustrating Strabo, *Chrestomathy*, 5.9–13 (Fig. 7.4). The image (very similar to the respective image in the *Tabula Peutingeriana*) condenses many of Strabo's pages (5.2.1–5.4.2), using a thick line to indicate a "mountain range" (τὸ Ἀπέννινον ὄρος) and a wavy line to suggest a river (Τίβερις ποταμός) or the sea shore (Ἀδριατική θάλασσα), using the convention proper to the *itineraria picta*. The figure puts the Adriatic sea on the top and the Tirrenum sea in the bottom, following the orientation of the Ptolemaic maps; besides, it mentions Picenum

89 Arnaud, *La cartographie à Rome*, vol. 3.1, pp. 985–91.

(Πικηνία χώρα) and the three tribes of Central Italy: Οὖμβροι, Σαβῖνοι, Μάρσοι. It is clear that this figure occurs as part of a Roman tradition of itineraries and it is a unique example of the combination of ethnography and toponymy provided by Greek descriptive geography with the hodological, properly Latin, representation of space by a Strabo's reader. Nevertheless this map of Central Italy raises several questions, which are difficult to answer. Was it found in the copy of Strabo used by the *Chrestomathy*'s author? Did the model have more maps of this kind? Why particularly Central Italy?

The *periplus* preserved by the Heidelberg MS belongs to a genre cultivated from the 4th century BCE to the 6th century CE, the practical nature of which has been questioned.[90] Except for two moments of intense recovery of texts involving the patriarch Photios and Maximos Planudes, the Byzantines do not seem to have a special interest in this genre, whose tradition they did not continue. However, under strange circumstances, at the end of the 10th century, a manuscript in Madrid, Biblioteca Nacional de España, Mss/4701, preserved a section of a so-called *Stadiasmos*, a Mediterranean *periplus*, which dates back to the Augustan era and was incorporated in the 3rd century by Hippolytus into his *Synagoge*.[91] Ultimately, in the 16th century, an epigone of the ancient *periplus* was born, the Greek portulan, which did not belong to Byzantine navigation knowledge, but to the western, mostly Venetian, tradition of navigational maps. These practical texts were conceived as tools for navigation in the Mediterranean, gathering information about winds, harbours, distances and geographical accidents, allowing sailors to determine their vessel's position.[92]

The absence of portulans does not mean that guides or itineraries were unavailable to the army or the administration. As an appendix of *De Cerimoniis* (2.45), dating back to 949, a short *stadiodromikon* was preserved, a list of stages (indicating the distance in stades between locations) of the journey from Constantinople to Crete.[93] The document fits in very well with the historical context of Byzantine attempts to conquer the island, then under Muslim rule; nevertheless it does not show the real route followed by the imperial navy, but according to Haldon, it must be understood as "a theoretical statement

90 González Ponce, "El corpus periplográfico griego," pp. 41–75; González Ponce, "Utilidad práctica, ciencia y literatura en la periplografía griega de época helenística," pp. 147–75.

91 Pérez Martín, "Chronography and Geography"; Arnaud, "Playing Dominoes."

92 All the texts edited by Delatte, *Les portulans*, are preserved in 16th-century manuscripts; cf. Gautier Dalché, "Portulans," who mentions the *Stadiasmos* as the only preserved Greek portulan written before the modern age.

93 Ed. Haldon, "Theory and practice," p. 235, cf. *ibidem*, pp. 301–02; Pryor/Jeffreys, *The Age of the dromon*, pp. 547–70.

of a desired route."[94] The *De ceremoniis* manuscript, Leipzig, Universitätsbibliothek, I, 17, preserves a short list of *aplekta* that cross Asia minor from Malagina to the Armeniakon (tit. "Exposition of imperial expeditions and roster of marching camps.").[95] The already mentioned manuscript Ambros. C 222 inf. (fol. 42), preserves a similar itinerary from Constantinople to Cyprus and Crete.[96] In any case, handbooks of warfare or administrative guides, mostly written in the Macedonian period, did not mention this kind of itineraria or maps.[97]

We know only of one rare testimony concerning the appreciation of geographical knowledge by a commander of the navy.[98] It is found in a later version of the work known as *Περὶ θαλασσομαχίας* and attributed to the general Nikephoros Ouranos (*c.* 980–*c.* 1010), a warfare handbook from the 11th century:

> While sailing into sea, it is in the commander's interest to keep by his side experienced men who know which winds make the sea move and which ones blow from the shore; and who may know of the rocks covered by the sea; the shallow waters; the navigated coastline; the islands in close proximity; the ports and the distance between them; and who may know, as well, inhabited places and watering points. For many have died,

94 Haldon, "Theory and practice," p. 302 and n. 251.

95 Ed. Haldon, *Constantine Porphyrogenitus, Three treatises*, p. 80.

96 Ed. Mazzucchi, "Ambrosianus C 222 inf.," pp. 430–31.

97 The reason may lie beyond the proverbial lack of definition of some Byzantine texts, given that it was considered inconvenient to write down strategic information that might find its way to the enemy; see Christides, "Two parallel naval guides," p. 85. According to Kowalski, *Navigation et géographie*, pp. 27–28, the absence of written records about sailing routes would confirm the vitality and usefulness of an orally transmitted knowledge, while an incomplete and therefore useless knowledge about an area of the sea shore, for example, would be written down in order to ease the possibility of its future completion and consultation. Emperor Leo VI's (866–912) *Taktika* mentions the importance of surveyors (§ 12.43, § 17.30, § 20.174), but pays no attention to itineraries or any kind of instrument to guide the march. The *Sylloge Tacticorum*, compiled during the reign of Constantine VII Porphyrogennetos, in a chapter *On the earth's measures* (a list of measurement units), gives the value of the *milion* "according to the precise geographers Eratosthenes and Strabo" (ed. Dain, § 2).

98 Ed. Dain, *Naumachica*, p. 93, who used the MS Firenze, Biblioteca Nazionale Laurenziana, Plut. 57.31 (16th c.). The text edited by Pryor/Jeffreys, *The Age of the dromon*, pp. 571–605 (here p. 575), is based on MS München, Bayerische Staatsbibliothek, Monac. gr. 452 (14th c.); on the text, see *ibidem*, pp. 181–83. In Pryor/Jeffreys' edition, this paragraph (according to the editors, a paraphrasis of Leo VI) is shorter and more vague, ignoring in fact the references to geographical knowledge. On Byzantine science of warfare, see chapter 12 of this volume.

inexperienced at sea and ignorant of these places, because the winds blew frequently and the ships dispersed. It is not only convenient for the commander to have experts on board such as those described, but also for every ship to have them, so that they may adequately advice on which is the best way to act.

## 5 Ptolemy, the Scientific Description of the *Oikoumene* and Planudes' Role

As previously pointed out, the main ancient text describing the *oikoumene* according to astronomical parameters which survived in Byzantium, was Ptolemy's *Geographike hyphegesis* (the real name of the text, although *Geography* is widely used).[99] The role played by Maximos Planudes in the survival of the work has given way to a complex and much debated issue, mainly focussed on the elaboration of the maps conceived by Ptolemy and transmitted along with the list of localities.[100] This sharp focus (or the disregard for Byzantine scholarship) has blurred other contributions to geography in the 14th century, which has fortunately been addressed by Basilios Tsiotras, who has studied the versions of the *Geography* by Nikephoros Gregoras and Isaak Argyros and the geographical materials of John Chortasmenos in MS Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 1059 and Urb. gr. 80.[101]

It would take a long time to describe every argument in favour or against the antiquity of the maps or the relationship among texts and maps[102] preserved by the earliest testimonies of the *Geography*, traditionally dating from the end of the 13th century,[103] but in any case we must present at least two kinds of

99 See Aujac, *Claude Ptolémée astronome, astrologue, géographe*. On the reception of the text in Byzantium, see Gautier Dalché, *La Géographie de Ptolémée en Occident*, pp. 71–86.

100 See Mittenhuber, "The Tradition," Burri, *Die Geographie.*

101 Tsiotras, *Ἡ ἐξηγητικὴ παράδοση*, pp. 71–193 and cf. Miller, *Die ältesten Separatkarten*, Laue/Makris, "Isaak Argyros." On the translation of the *Geography* in Florence, see Gautier Dalché, "The Reception," and Id., *La géographie de Ptolémée en Occident*.

102 Berggren/Jones, *Ptolemy's Geography*, pp. 45–46, establish two main categories of sets of maps, either directly coming from or not dependent of Vat. Urb. gr. 82. The scheme preferred by Ptolemy himself (10 maps of Europe, 4 of Lybia, 12 of Asia) required big sheets to accommodate the maps (this is what Diller calls "Atlas-branch"). The second category multiplies the maps and splits some regions into two or more parts, in order to reduce the size of the codex.

103 The more precise dating around 1295 comes from a mistaken appreciation (see f. ex. Pontani, "The World," 181 and 190) of Planudes' *ep.* 119 (dating from the spring of 1294, see Beyer, "Die Chronologie," 121), in which the scholar expresses his desire to possess the books of Ptolemy (τὰς Πτολεμαίου μοι βίβλους γενέσθαι). The *Geography* is not the only

evidence, the manuscripts and the texts, in order to clarify the Byzantine intervention in the textual transmission.

Some points seem certain: a poem by Gregory of Bulgaria claims that "it was thanks to your (sc. Planudes') labours that Ptolemy's labour, hidden in the depths of oblivion, was revealed in numerous images."[104] Secondly and more important, an epigram by Planudes[105] states that "the *Geography* has just come to light" and congratulates Andronikos II for that enterprise, which locates the recovery of the text after 1282 under the patronage of the emperor. Planudes played a very active role in the recovery of texts, either scattered (such as Plutarch's *Moralia*) or preserved in bad shape (Diophantus), just to mention two. That Andronikos II supported him in this task is beyond any doubt, but in Ptolemy's case aid was more necessary than ever, because of the monumentality of the operation. Nevertheless the texts of the epigram do not specify the intervention of Planudes in the project and its title was not written by Planudes himself, since it varies depending on the testimony. The oldest witness of the poem is MS Milano, Biblioteca Ambrosiana, A 119 sup., on whose fly-leaves (fols. IIv–III) some students of Planudes gathered and transcribed a group of poems related to Ptolemaic *Geography*.[106] This means their copy is the closest to the scholar. The title reads as follows: "Of the most holy and wise sir Maximos Planudes, on the diagram of Ptolemy that he himself conceived and drew from the book of Ptolemy, without taking his cue from anyone else."[107] This "diagram" must be the general map of the *oikoumene* based on Ptolemy's text,

Ptolemaic writing Planudes dealt with and therefore the letter does not suggest a date for the *Geography*'s recovery.

104 Ed. and transl. by Pontani, "The World," p. 193–4, and Chrysochoou, "Maximos Planoudes," pp. 127–28, from Ambros. A 119 sup., fol. IIv.

105 First publication by Stückelberger, "Planudes," a new version in Pontani, "The World," 197–9, with English transl., but also and independently by Mazzucchi, "Il Tolomeo Ambr. D 527 inf.," pp. 263–64, with Italian transl.; see also Chrysochoou, "Maximos Planoudes," 123–4 (who does not know Pontani's or Mazzucchi's papers and in pp. 123–27 wrongly assigns to Gregory of Bulgaria all the poems in Ambros. A 119 sup. and to Planudes a fragment in Nikephoros Gregoras' notebook Palat. Heidelb. gr. 129), and Mazzucchi, "Ancora sugli esametri." The most recent edition (with French translation and commentary), by Taxidis, *Les épigrammes de Maxime Planude*, pp. 87–97, and *ibidem*, pp. 97–102, other poems related to Ptolemy's *Geography*.

106 Mazzucchi, "Il Tolomeo Ambr. D 527 inf.," p. 262 and n. 16, "Ancora sugli esametri," 183–4, nn. 6–7, identified the hand of John Zarides on fol. III and imprecisely on fol. IIIv the main hand (A) of the Strabo Marc. gr. XI.6, for which see Cohen-Skalli/Pérez Martín, "La *Géographie* de Strabon," where we propose to identify the scribe with a student of Planudes, Georges Lakapenos. In Ambros. A 119 sup. we see his hand, surprisingly similar to Planudes,' on fol. Iv, the top of fol. IIv, and the poem Εἰς τὰς ιβ' ἑορτάς on fol. IIIv.

107 Transl. by Pontani, "The World," p. 192.

and to be distinguished perhaps from the entire set of maps,[108] but clearly designed by the Byzantine scholar merely from Ptolemy's text. Another, later, testimony of the poem (MS Napoli, Biblioteca Nazionale, Neap. III.C.3) shows a different title: "(…) Heroic lines on Ptolemy's *Geography*, which had disappeared for a long time and was then found by him with great toil."[109] If the title is contemporary with the copy of the Naples manuscript, we must date it a century after the recovery, when the legend of Planudes, the book-hunter or recoverer of Greek texts, was already set. Also, the famous Latin note written in Vat. gr. 177 (fol. IIv: *Claudii Ptolomei liber geographie et est proprius domini Maximi philosophi greci ac monaci in monacerio Chore in Constantinupoli emptus a quodam Andronico Yneote*) may be understood in terms of Planudes' fame, if the Maximos monachus mentioned was indeed Planudes and the westerner who bought the manuscript did it with the belief that he was buying Planudes' very exemplar.[110]

Regarding the manuscripts: the earliest copies of the *Geography*, hypothetically linked by Diller to Maximos Planudes, have deserved much attention, although their palaeographical analysis is sometimes faulty.[111] Literature on the subject ignores, for example, that the MS Vat. gr. 191, an important but incomplete copy without maps of the *Geography* and many other geometrical and astronomical texts, is a miscellany organized by John Pediasimos, *hypatos ton philosophon* and rival of Planudes.[112] Furthermore, although neither the Planudean copy of the *Geography*, nor even a manuscript of this text annotated by him have been preserved, the oldest manuscripts (Vatican, Biblioteca Apostolica Vaticana, Urb. gr. 82 and İstanbul, Topkapı Sarayı, Seragl. G.I.57 +

108 Chrysochoou, "Maximos Planoudes," pp. 124–25, thinks that "diagram" does not refer to a map but to the graticule of meridians and parallels. It is true that diagram usually stands for the schema or figure resulting from a demonstration, but such a figure would contradict the description given by lines 15–18 of the poem and it would not deserve such a laudatory text. The map of the *oikoumene* is drawn on the basis of the graticule and of Ptolemy's calculations, and this explains its name, which reinforces the scientific value of the operation.

109 Transl. Pontani, "The World," 199.

110 Against the identity of "Maximus philosophus monachus" with Planudes, see Estangüi, "Saint-Sauveur de Chôra." On the identity of Andronikos Oinaiotes, see *ibidem*, 154–61.

111 The Swiss team of classicists who edited the *Geography* in 2009 have published several studies on the textual transmission and the manuscripts; see at least Mittenhuber, "The Tradition"; Stückelberger/Graßhof (eds.), *Klaudios Ptolemaios. Handbuch der Geographie. Ergänzungsband;* Burri, *Die Geographie;* Defaux, *The Iberian Peninsula in Ptolemy's Geography.*

112 Pérez Martín, "L'écriture de l'hypatos," and Acerbi, "Byzantine Recensions," 192–5. According to Berggren/ Jones, *Ptolemy's Geography*, p. 44, Vat. gr. 191 is the only copy uninfluenced by a Byzantine revision.

København, Det Kongelige Bibliotek, Haun. 23 (1 fol.), the "Atlas-branch" of the transmission), have been linked to Planudes since Diller's study in 1940. According to Diller they were produced under Planudes' personal direction, but the evidence gathered by the American scholar is very scant. It is based on the fact that the first scribe of Seragl. G.I.57 also copied Strabo's manuscript Paris, Bibliothèque Nationale de France, gr. 1393, from which Planudes selected some passages for his *Sylloge*.[113] Another testimony to the "Atlas-branch" of Ptolemy's text is an anonymous *Diagnosis*, preserved by Paris, Bibliothèque Nationale de France, suppl. gr. 443A (fol. 10) and other later codices. Diller has argued that Planudes may be the author, but the question has not been clarified.[114] Therefore the involvement of Planudes in this group of testimonies would be based on the equation imperial patronage = lavish manuscripts. In fact, Planudes' handwriting has not been found in any of these manuscripts (and we are well aware of Planudes' willingness to take to the pen and write, correct or comment on a text).

Ptolemy or Strabo[115] were not the only roads to geographical knowledge considered by Planudes. He also read Cleomedes' astronomical treatise *De cyclica theoria* (*Cyclic Theory*, written around 200 CE), which offers the most informative account of Eratosthenes' method of measuring the circumference of the Earth, and copied part of the oldest preserved copy.[116] Cleomedes' treatise had been the source of a long excerpt linked to Psellos' teachings and preserved in a miscellany copied by the middle of the 13th century in the MS Oxford, Bodleian Library, Barocci 131.[117] Likewise, in the approach to the physical geography embedded by Nicephorus Blemmydes (1197/8–1271/3, the most influential scholar in Byzantium in the central decades of the 13th century) in his *Epitome physica*,[118] Cleomedes was the main source used by him. Two geographical texts attributed to him were not written by Blemmydes, but represent 16th-century forgeries.[119] Instead, his *Epitome*, a compilation intending to

113 Diller, "The Oldest Manuscripts," pp. 65–66.

114 Diller, "The Anonymous Diagnosis," and Wolska-Conus, "Deux contributions," 259–73.

115 Strabo's books 1–2 are a fascinating introduction to the ancient geographical thought that used to be read along with Ptolemy's book 1, see Chrysochoou, "Maximos Planoudes," pp. 117–18.

116 Todd, "The Manuscripts." The text was contemporarily commented by John Pediasimos for his students: his scholia have been edited by Caballero, *El comentario*.

117 The miscellany was published by Pontikos as a text in itself and in this edition the chapter from Cleomedes is § 30; see Pontikos, *Anonymi Miscellanea Philosophica*, pp. 93–96, where the text also deals with the climates and belts, the antipodes, etc.

118 Lackner, "Zum Lehrbuch der Physik," p. 164.

119 Diller, "Two Greek Forgeries"; Brodersen, "Die geographischen Schriften" (*pace* Koder, "Nikephoros").

assemble the most relevant philosophical subjects, and still lacking an appropriate edition,[120] presents three chapters (§ 28–30) dealing with the foundations of astronomical geography: the measurement of the earth and the belts or climates, the antipodes, the length of day and night, the seasons, and the habitability of the earth.[121]

Finally, in the realm of astronomical geography we still need to recall a text already mentioned, this time not written in Greek but translated into Greek by Planudes, Macrobius' *Commentary on the Dream of Scipio*, a scientific compendium that successfully transferred the Greek geographical and astronomical wisdom to the Latin west, using as an excuse the *Dream of Scipio*, the worldview and oracles of Scipio Africanus which close Cicero's *Republic.* The geographical section (2.5–9) is presented as the natural extension of the astronomical chapters and deals succinctly, although substantially, with the terrestrial belts and their measures, the antipodes, the ocean and the inhabited world.[122] Although Macrobius' editors do not attribute any textual value to the Greek translation of the text,[123] the Planudean version, preserved in several Byzantine copies, did constitute a recovery of the Greek tradition defending a theory of the earth's surface that had faded away a long time ago, namely Crates of Mallos' theory on the four inhabited worlds.

## 6 Conclusion

In this chapter it has emerged that Byzantium collected, transformed, and adapted to its own concerns and cultural parameters different geographical traditions and practices, much as happened in other scientific disciplines. In this case though, peculiar and positive conditions exist: on one side, geography established the ideal of a universal empire, independently from the meagre reality, through the emphasis on the spatial and cultural continuity from the very inaugural moment of the Homeric poems; on the other, it enhanced the diversity and perfection of the divine creation expressed through the richness and the natural variety collected by descriptive geography. Therefore, the

120 Ed. *PG* 142: 1269–1299. Stefano Valente prepares its edition; as a hint for the content and the school context, see Valente, "The Doctrine of Winds."

121 Blemmydes' influence is evident in the outnumbered writings of the emperor Theodore II Laskaris on nature; for the centrality of the Greek territory in his thinking, see Koder, "Die *Hellenis* als Mitte der Ökumene," pp. 195–205.

122 Stahl, "Astronomy and Geography," pp. 249–58.

123 Macrobe, *Commentaire*, ed. Armisen-Marchetti, the most recent edition, does not even mention it. A reappraisal of the translation in Pavano, "Osservazioni."

confluence between the Alexandrian and Roman approach to the world and the Christian cosmology took place without shrillness or insoluble contradictions.

Consequently, it is no accident that the geographical poem of Dionysius Periegetes was so diffused and studied, or that Strabo found in Byzantium and the Renaissance the place he could not get in his own period's geographical tradition. These facts have to do with the descriptive conditions, accumulative and encyclopaedical, shared by both works together with another celebrated one: the *Tabula Peutingeriana*. But if the outcome of the Byzantine geographical tradition was the recovery of Ptolemy that took place in the imperial learned circles, this was not a matter of chance either, but an eloquent fact about the cultural and scientific Byzantine practices. The Alexandrian scientist embodied tradition as well as change: tradition because his work represented the outcome of the wisdom accumulated for centuries in the environment of the Library; change because his lasting spherical projection of the earth meant the final overcoming of the anomaly between the spherical outlook of the world and the orthogonal projection of the map. By doing so, in a natural way, Byzantine geographical knowledge assumed the map that accompanied and completed the textual information.

We may conclude this approach to the geographical knowledge in Byzantium by paraphrasing Planudes' words in the epigram on the *Geography* of Ptolemy mentioned above. In lines 19–27,[124] Planudes, the outstanding scholar who studied all the available ancient poetry and at the same time worked on the mathematical inheritance of antiquity, makes a declaration of principle when he recommends ignoring what poets say on the ocean surrounding the *oikoumene* and declares the superiority of Ptolemy over Dionysius of Alexandria. A good point to state and reassess what Science meant for the Byzantines.


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124 Taxidis, *Les épigrammes de Maxime Planude*, pp. 87–88.

CHAPTER 8

# Zoology

*Arnaud Zucker*

## 1 Introduction

In the field of zoology, the Byzantine era is regarded as scientifically unproductive at best, or at worst a scientific black hole. The purpose of this contribution is to challenge this view and provide a fairer and more exhaustive overview of post-antique Greek zoological literature. Due to the lack of any long-lasting and consistent tradition, Byzantine production will never contribute a real chapter to the history of zoological science, but not only did this period pass on major witnesses of ancient achievements to modern readers, it also gave birth to significant works or original genres displaying, if not renewing zoological knowledge. Actually, the denigration from which Byzantine zoological production suffers could be said to apply more or less to the whole literature after Aristotle until the sixteenth century.[1] Historians and Byzantinists indeed lament that Alexandrine scholars as well as Latin and later authors not only abandoned the path opened by Aristotle in biology, physiology and comparative anatomy but seem to have been content with tirelessly describing and praising "the paternal love of the stork, the musicality of the nightingale, the wisdom of the elephant, the migration of the cranes …"[2] In Byzantine times, living beings are supposed to be only worth knowing as medicine stock, economic resources and theological proof of God's providence. Yet, theoretical and applied research on biological characteristics as well as experimental and methodical investigation on physiology and ethnology constituted an 'Aristotelian' exception in zoology. However, Byzantine zoological works have received very little attention so far, much less than the 'canon' of well-identified witnesses of the Roman period, particularly Pliny (1st century), Plutarch (2nd century), Oppian of Cilicia (2nd century), Oppian of Syria (3rd century) and Aelianus (3rd century), who have been the focus of substantial study.

In the books dealing with the history of zoology, such as Petit and Théodoridès's work, no text in the field is reported after Aelian's *De natura animalium*

1 See Lennox, "The disappearance of Aristotle's biology"; Föllinger, "Biologie in der Spätantike."

2 Aelian, *De natura animalium* (*On the Characteristics of animals*), ed. García Valdés et al., epilogue l. 12–18, p. 430.

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(*On the Characteristics of animals*) (early 3rd century). The authors state that "le seul nom qui émerge de l'obscurité du Moyen Age est celui d'Isidore";[3] and E. Mayr is very much at one with that view when he argues: "Nothing really important emerged in biology after Lucretius and Galen until the Renaissance."[4] The very comprehensive *History of Science* by Sarton (1931) itself devotes very few pages to Byzantine zoology, considering Chinese, Arabic and later Latin achievements as much more valuable. It remains, therefore, an underestimated field of Byzantine scholarship and a relatively unexplored aspect of Byzantine culture, largely undocumented by current dictionaries of Byzantine literature, except by Hunger,[5] who devotes six penetrating pages to the topic: Krumbacher[6] alludes to some texts (*Physiologus*, Timotheos, treatises of falconry, late Byzantine commentaries, Manuel Philes) in less than one page; Každan has very scant entries[7] and Lagerlund none.[8]

It is claimed that Byzantine achievements in zoology are very insignificant when compared with Islamic production, which developed speedily from the 8th century onwards, but was not translated before the late 11th century and hardly emerged in the zoological field of Greek literature. This can also be seen in the rare and late linguistic loans from Arabic (e.g. *gadaros*, donkey).[9] Though not being a major science either in the Arabic theoretical classification of sciences (and less flourishing than botany), zoological concern and knowledge nevertheless grew to a considerable extent. It was inspired by the early translations and diffusion in Syriac and Arabic of Greek treatises, chiefly of the Aristotelian corpus. Important Arabic zoographers, such as Al-Jāhiz (*Book of Animals*, *c.* 847), Abū Ubaidah (author of more than fifty books on the study of the horse, 8th–9th century), Al-Masʿūdī (in *Meadows of gold*, 9th–10th century), Al-Marwazī (*Nature of animals*, *c.* 1120), Al-Tawhidi (in *Enjoyment and Conviviality*, 10th–11th century), Al-Qazwīnī (in the *Wonders of Creation*, 13th century) or Al-Damīrī (*Life of Animals*, *c.* 1371) and authors of early anonymous treatises (Pseudo-Ibn Bukhtīshūʿ, *Book of the Characteristics of Animals*, *c.* 825; *Book of animals*, ante 850) reached a very high level of specialization and refinement and tackled mainly biological issues.[10] Remarkably, these texts

3 Petit/Théodoridès, *Histoire de la zoologie*, p. 154.
4 Mayr, *The Growth of Biological Thought*, p. 1135. See also Nordenskiöld, *The History of Biology*, pp. 58–61, 74–75.
5 Hunger, *Die hochsprachliche profane Literatur der Byzantiner*, II, pp. 265–70.
6 Krumbacher, *Geschichte der byzantinischen Litteratur* (chap. 7, § 261), pp. 631–33.
7 *The Oxford Dictionary of Byzantium*.
8 *Encyclopedia of Medieval Philosophy*.
9 From Arabic *gadar-gaidar*, in Greek manuscripts as early as 6th century CE (see Kriaras, *Λεξικό της μεσαιωνικής ελληνικής δημώδους γραμματείας 1100–1669*, vol. 4, p. 215.
10 See Ullmann, *Die Natur- und Geheimwissenschaften im Islam*, esp. pp. 6–61.

never refer to any Byzantine writer, with the exception of Timotheus of Gaza. It is therefore no surprise that Byzantine *Lexica* should fall far short of the unsurpassable richness of zoological vocabulary in Arabic literature to describe certain species of animals. There are, for example, more than a hundred words for naming the horse or the camel depending on their sex, age, colour, anatomy, etc. in the writings of the Arabic philologist Al-Asmaʿi of Basra (8th–9th century) who composed books *On the Horse*, *On the Camel*, *On the Sheep*, *On Rare Animals* and *On Wild Animals*.[11]

Still, the first difficulty one encounters in dealing with Byzantine zoology is the absence of any specific discipline or identified field of science. This modern word might even appear as entirely irrelevant in this cultural context, much more perhaps than many categories we usually believe to have some sort of semantic permanency (such as philosophy, astronomy or rhetoric, etc.), though in fact their meaning also changed greatly over time. Even though zoology, in the form of a unified field, did not exist as such, we can nevertheless identify intellectual activity that reveals a special concern for animals. As a matter of fact, even if zoology is not a Byzantine science or a methodical study in the contemporary sense, we cannot deny the existence of a substantial amount of literary evidence for zoological knowledge. The corpus that is most likely to provide evidence of discourse on animals is, however, particularly difficult to specify. In fact it should legitimately encompass texts whose content is related to a large array of modern disciplines such as Pharmacy, Agriculture, Animal Husbandry, Veterinary Medicine, Psychology, Ethics, and Theology. The negative judgement of historians on Byzantine achievements in this regard has resulted in reinforcing a lack of interest in this kind of text, thus keeping them in relative obscurity, and leaving Byzantine documentation without a systematic inventory. It is in this context, that this chapter aims at providing a critical overview of the texts written in Greek in the Eastern part of the Roman empire displaying zoological knowledge and interest. In so doing we have to put aside current prejudices because we are aware of how much depends on our epistemological and ontological assumptions. Bearing in mind this caveat, before reviewing the main textual sources it is worth discussing first the principal arguments offered in explanation for the low level of Byzantine scholarship in zoology.

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11 For the editions, see R. Geyer, *Das Kitäb al Wuhush von al-ʾAsmaʿi mit einem Paralleltexte von Qutrub*, Vienna, 1887 (*Book of the Wild Animals*); A. Haffner, *al-Asmaʿī. Kitāb al-khail*, Vienna, 1895 (*Book of the Horse*); A. Haffner, *al-Asmaʿī. Kitāb al-shāʾ*, Vienna, 1896 (*Book of the Sheep*); D.H. Müller, *al-Asmaʿī. Kitab al-Farq*, Vienna, 1876 (*On Rare Animals*); A. Haffner, *Texte zur arabischen Lexikographie*, Baghdad, 1905, pp. 66–157 (*On the Camel = Kitab al-Ibil*).

## 2 Cultural Contexts

### 2.1 *Institutional Frame*

Two main reasons have been put forward. The first is the absence of any institutional framework within which zoology could have developed. How can a discipline live or even survive when it is totally absent from education and the school curricula? There was indeed no room for biological knowledge in any philosophical school, nor any chair in the higher education systems of the Imperial Schools, either in Constantinople or in the Greek Byzantine area (on scientific teaching in Byzantium, see chapter 2 of this volume). Apart from the literary treatises, the regular process for the transfer of practical knowledge (esp. in veterinary medicine) seems to have been hands-on experience and private learning with a specialist in zootechnical context. The Imperial School, established after the founding of the new metropolis and known as Mega or Ecumenical Didascaleion, School of Capitolium, Imperial Auditorium, Pandidacterion…, never included this kind of teaching, even after its overhaul and expansion by Constantine IX Monomachos in the 11th century.[12] Unlike the Islamic House of Wisdom (Bayt al-Hikma), a university of sorts founded in Baghdad as early as the 9th century and active until the 13th century that supported all kinds of scientific undertakings, no major Byzantine intellectual centre ever included biological teaching or studies. These *naturalia* were probably not considered as engaging as celestial objects, so they were simply left out of the Greek *Quadrivium* (μαθηματικὴ τετρακτύς), probably because they lacked pedagogical value (in contrast to logic and theology), and a dialectic dimension in biology. Whatever the motives, this situation was rather a consequence than a cause. Through private tutorials in higher education Imperial Schools or learned parallel circles, a syllabus for studying living beings could very well have been put into place.

### 2.2 *Christian Doctrine*

However, the main argument is that basically Christian dogma runs counter to any kind of commitment to natural science. Indeed, conventional thinking has it that most Byzantine intellectuals were strictly subservient to the Holy Scriptures, which were assumed to prevent the progress of the sciences (see chapter 1 of this volume).[13] The fact is that Church Fathers, when expressing their opinion on natural sciences, generally took a two-faced position,

12 See Theodosiou et al., “The Contributions of the Church in Byzantium to the Natural Sciences,” p. 60; Nikolaïdis, *Science and Eastern Orthodoxy*.

13 Petit/Théodoridès, *Histoire de la zoologie des origines à Linné*, p. 182.

considering that knowledge is valuable only to the extent that it contributes to deepening the understanding of God's words in the sacred texts. Theology is not only the overarching science but also the ultimate scope of any study. As Basil states, criticizing the philosophical disputes on the shape and size of the earth: "God has passed over in silence, as useless, all that is unimportant for us. Shall I then prefer foolish knowledge to the oracles of the Holy Spirit?"[14] Natural investigation is as suspicious as allegory, being sources of both understanding *and* of misconception, of faith *and* of danger. Augustine has similar views on the "empty science"[15] and what he calls *cupiditas cognitionis et scientiae*.[16] In *De christiana doctrina* (On Christian Teaching) he encourages Christians to go into natural knowledge in greater depth, in order to praise the wisdom of God,[17] since studying "the nature of animals" helps solve the difficulties of Scripture.[18] Yet he prevents them from uncontrolled use of Pagan knowledge arguing that "knowledge puffs up, but charity edifies."[19] However, to assume that the eclipse of zoological science in Byzantine times lies in the contradiction between theology and epistemology would be a substantial misunderstanding. First, because this position is not clear-cut and quite ambiguous towards 'pagan' tradition. This can be seen in the rather open-minded attitude towards Greek literature in general shown by the same Basil in his *De legendis gentilium libris* (*Address to Young Men on Greek Literature*). Natural knowledge, is both a prerequisite for understanding the Scriptures and a possible cause for straying from God's path, but it leaves the way open for the scientific interest in the natural sciences that authors such as Origen, Nemesius or Basil himself clearly demonstrate. We should also keep in mind that "practically all important scholars working in Mathematics, Astronomy and Physics, were monks, or men of Church" in general.[20] In addition, we must refrain from overestimating both the impact of isolated statements made by individuals and even the general influence of Christian dogma on the different aspects of Byzantine culture. It would be naive and unrealistic to believe that Byzantine life was conditioned by the writings or (contradictory!) ideas of priests and bishops. It would also be unrealistic to force the Byzantine empire into a kind of modern theocracy and imagine that to a large extent religion ruled both social life and

14 The expression is from Basil, *Homiliae in Hexaemeron* 9.1 (189A), ed. Giet, p. 482.
15 The expression comes from Basil, *Homiliae in Hexaemeron* 9.7 (181B), ed. Giet, p. 466.
16 *Confessiones*, ed. Hammond, 10.35.54, p. 161.
17 *De christiana doctrina*, ed. Moreau, 2.16.24.
18 *De christiana doctrina*, ed. Moreau, 2.29.45.
19 The quotation is from 1 Cor. 8:1.
20 Theodosiou et al., "The Contributions of the Church in Byzantium to the Natural Sciences," p. 58.

the people. Both explanations for the fact that Byzantines seemed to neglect biological issues are thus limited and unsatisfying. They fail to account for the literary dilution of zoological commitment.

### 2.3 *Anthropozoological Relations*

Besides, there is no reason to assume a radical change in worldview with respect to natural beings. Human interaction with animals was as constant and manifold as previously.[21] Archeozoological data provides substantial evidence that a wide variety of animals were utilized in diet or for economic and technical purposes.[22] The Eastern Roman empire tended to develop closer contact with Persia, India and the growing power and emerging culture of the Arabian world. This did not induce significant ecological mutations but made exotic fauna and animal products more familiar through trade and diplomatic relations. The exchange of animals as diplomatic gifts is well documented by Greek and Arabic sources through the period, and consisted mainly of horses or mules, but also elephants, giraffes, lions, dogs, cheetahs, falcons…[23] We have substantial reports of the giraffes received by Anastasius from an Indian prince in 496, by Constantine IX from the sultan of Egypt in 1053, or by Michael Palaiologos from the king of Ethiopia in 1257, which were paraded for a few days through the streets of the City for public entertainment. Apart from livestock of all kind, game parks outside cities (such as the Philopation, north of Constantinople) or types of 'menageries' within cities (e.g. the zoo established in Constantinople by Constantine IX Monomachus) bear witness to continuous contact for hunting and pleasure with various species; after the fall of the Byzantine empire visitors to Constantinople report that a wide array of animals could be seen in several places of the city, including churches and the Great Palace of Constantinople: lions, panthers, lynxes, wolves, bears and tigers, elephants, hippopotamuses, and camels.[24] The hippodromes, constructed throughout the empire in late antiquity, provided a setting for popular horse-racing, and various shows of wild animals were performed in amphitheaters: In 521, Justinian, whose wife Theodora was previously a goose dresser performing in the amphitheater,[25] organized expensive games with twenty

21 See Koukoules, "Περὶ τὴν Βυζαντινὴν οἰκίαν."

22 See Kroll, "Animals in the Byzantine Empire," pp. 93–121.

23 See Ševčenko, "Wild animals in the Byzantine Park"; Buquet, "Arab and Ottoman Menageries" and "Les animaux exotiques dans les ménageries médiévales"; Drocourt ("Les animaux comme cadeaux d'ambassade") misses a full range of references.

24 See Buquet, "Arab and Ottoman Menageries."

25 Procopius, *Historia arcana* (*Secret History*), ed. Haury, 9.20, pp. 59–60.

lions and thirty panthers.[26] Animal hunting, often practiced in open territory, was also performed in the two amphitheaters of Constantinople at least until the 12th century. Thus people, including those in urban areas, had many opportunities of physical contact with animals and their many depictions in public or private painting and mosaic across the empire.

### 2.4 *Animal-Related Literature*

In spite of all that, there is no unified tradition within Byzantine texts involving animals which conveys any kind of zoological information, and there is no dominant thread that would help establish a general picture of the relevant literature. However, it is possible to differentiate specific traditions both by the kind of sources on which the authors rely, and the literary genre to which the writings belong. Even Aelian (3rd century), which is by far the major and most popular source for the texts of this corpus, is absent from technical and historical texts. Aristotle appears as rather a common, but generally second-hand reference and only late commentators (such as Michael of Ephesus in the 12th century) and some philosophers like Psellus (11th century) draw directly from his work. The porosity of generic traditions, perceptible in Hellenistic times, decreased during the Imperial Roman period and afterwards. Learned scholars may well have read numerous and various texts, but in the field of animal issues, their work seems to depend on special and restricted documentation. It would be easier to specify these traditions and to describe more precisely how Byzantine authors connected with classical zoological treatises, had they made their sources explicit. The different traditions distinguished in the following sections are not only pointed out for the sake of clarity to sort out the principal sources, but they also correspond to conspicuously distinct trends and purposes.

## 3 The Constantine Encyclopedia and Timotheus of Gaza

### 3.1 *The Constantine "Encyclopedia" (10th Century)*

The only surviving book dealing specifically with animals and uncontroversially meeting the modern criteria for zoological literature is a compilation achieved around 950 and dedicated to Constantine VII Porphyrogennetus, a *Συλλογή*, first edited by S. Lambros in 1885 from a *manuscritus unicus* under the alternative name of *Aristophanis Historiae animalium epitome* and *Excerptorum Constantini de natura animalium libri duo*. Only two books out of four

26 Marcellinus Comes, *Chronicon*, Ind. XIV, in *PG* 51, col. 940.

(*c.* 38,000 words) are preserved (a general introduction and the incomplete book on quadrupeds). It brings together information on viviparous and oviparous animals, and operates an instructive selection on the literature on animals available in the 10th century considered as worth copying and transmitting.[27] The general organization of the book, which constitutes a kind of *Zoological Reader's Digest*, apparently follows the structure of an Alexandrine *Epitome* of Aristotelian zoological corpus ascribed to Aristophanes of Byzantium (3rd century BCE), methodically supplemented with layers of various later authors.[28] It is therefore difficult to determine the purpose of the compiler, whose textual interventions appear to be limited to a brief poetical dedication pointing out animal "behaviour, dwelling and natural properties" and a general title: "Collection carried out for the great king and Emperor Constantine concerning terrestrial, winged and marine animals." Obviously, if Aristophanes aims at providing an Aristotelian *textbook*, the Byzantine compiler intends to achieve a literary *sourcebook* on animals. This collection produced during the so-called "First Humanism,"[29] belongs to the encyclopedic turn given by Constantin VII Porphyrogennetus.[30] Though not being included in it, it is correlated with the huge and prestigious editorial undertaking known under the complementary names of *Excerpta* or *Collectanea*, and comprising 54 sections on different topics, 5 of which are more or less preserved to date (*On imperial public proclamations*, *On embassies*, *On virtue and vice*, *On tricks against the kings*, *On maxims*) and 19 merely known by title.[31] The first book of the *Συλλογή* is entirely drawn from Aristophanes' work, and probably consists of a copy of its first book, divided into three sections: a survey of the taxonomic Aristotelian terminology; a systematic overview on reproduction depending on the natural classes with a special chapter on the issues of semen and embryo; an inventory of animal and human peculiarities and oddities. The second book deals successively, in a monographic way, with all quadrupeds arranged according to Aristotelian anatomical categories from elephant to horse after a

27 It is not clear whether the original edition was complete. Photius (*Library*, cod. 161, p. 104b26–36) mentions *Excerpts* of the sophist Sopatros (4th century) only drawn from the two first books. See Berger, "Die Textgeschichte der *Historia Animalium*."

28 See Hellmann, "Antike Verkürzungen biologicher Texte," pp. 559–70.

29 Lemerle, *Le premier humanisme byzantin*; See also Cheynet/Flusin, *Autour du "Premier humanisme byzantin."*

30 He is called *libris incumbens* by italian ambassador Liutprand; see Lemerle, "L'encyclopédisme à Byzance," p. 599 and *Le premier humanisme byzantin*, p. 269. On a critical reassessment of the Constantine's encyclopedic turn, see Odorico, "La cultura della συλλογή."

31 Lemerle, *Le premier humanisme byzantin*, pp. 280–85.

large inaugural section on man.[32] Every chapter completes the programme expounded in the preamble: "I will first indicate the name of the animal I am dealing with; then successively all the anatomical parts possessed by the animal in question; then its mode of coupling, how many months the gestation lasts, and concerning reproduction, how and how many offspring it can bear; then the way of life of the animal, its behaviour and its longevity."[33] To this Alexandrine and systematic block, representing about 38 per cent of the whole *Συλλογή*, the compiler adds in a regular order, excerpts (sometimes abridged) drawn from Aelian, Timotheus of Gaza, Pseudo-Aristotle's *Mirabilia*, Basil's *Homiliae in Hexaemeron*, and occasionally from Ctesias, Agatharchides and Philostorgius. The arrangement singles out first a major chronological series consisting of Aelian's and Timotheus' (6th century) works, representing respectively 43 per cent and 13 per cent of the *Συλλογή*, before a second one comprising the remaining sources (from Ctesias to Philostorgius). We can assume that the first two authors, who incidentally are both "sophists," are ranked scientifically higher in the compiler's conception, but the contrast is mainly based on the fact that both devoted an *entire* work to animals, while the further providers of zoological information did not write a specific book on them but dealt only casually with animals. Basically, no epistemological discrimination can be found here (as elsewhere in the zoological tradition) between what we would call *specialists* and general literature. In a similar way, Aelian together with Pliny mention, on the same footing, Homer and Aristotle, the ichthyologist Leonidas of Tarent (3rd century BCE) and the historian Hecataeus of Miletus (6th century BCE). In addition to this, it is striking that no post–6th century author appears in the collection. Since only one excerpt is drawn from Philostorgius (4th–5th century), namely a depiction of the giraffe, the selection emphasizes both the exceptional status of Timotheus' book *On animals*, and the general absence of Byzantine writers. This might result from fortuitous causes, such as the unavailability of some books, or from the choice of the compiler to deliberately omit fresh documentation in the miscellany, but we cannot rule out the possibility that he simply did not find any new written material worth mentioning in more recent texts. All in all, the fact is that the *Συλλογή*, like the *Geoponica* or the *Hippiatrica* (see below), is, judging from its content, more contemporary to late antiquity than to the Macedonian renaissance. As in the remainder of Byzantine literature (and already in Alexandrine times), Aristotle is only an *indirect* source, and the selection suggests the recog-

32 Note that the second book is not complete. Thanks to a fragment of an epitome of the *Συλλογή* (Florence, Biblioteca Medizea Laurenziana, Plut. 86.8) we can infer that the second book originally also included chapters on ass, onager and selachians.

33 *Excerptorum Constantini de natura animalium libri duo*, ed. S. Lambros, B 1, p. 35, l. 18–36, l. 3.

nized position of Basil as a naturalistic reference (see below). Furthermore, the prominent role played by Aelian in zoological tradition, provides further evidence of the popularity of his work. His work *De Natura Animalilum* was copiously used by Basil and continually read in Byzantine times (George of Pisidia, Suda, Byzantine collections of Proverbs, John Tzetzes, Eustathius, Manuel Philes…).[34] Clearly it was considered essential reading. Due to the literary purpose of the compiler, no specific biological concerns can be traced in the *Συλλογή* apart from the Aristotelian components, and neither science, nor techniques, crafts or economic issues seem to be tackled here.[35] It is worth noting, by the way, that the rich terminology list appearing at the beginning of the first book and explaining the meaning of "solipeds," "arthropods," etc.[36] has no echo at all in the remainder of the book even in the Aristophanes sections. The autonomous fate of this short list, reproduced separately in a dozen manuscripts, shows that the specialized taxonomic vocabulary was eventually regarded as a (mere) lexicographic issue.

### 3.2 *Timotheus of Gaza*

If we focus on the Byzantine components of the *Συλλογή*, the only fresh contribution consists in excerpts (sometimes slightly abridged) of Timotheus' *De Animalibus* (On Animals) for 18 animals (*c.* 4,800 words). This work, written in sophisticated prose and composed around 512 CE, when the famous illuminated edition of Dioscorides was produced and presented as a gift to Julia Anicia (see below), is otherwise known through an 11th century summary,[37] containing 54 zoological chapters. Scanty biographical information is afforded by the Suda (T 621, ed. Adler) on this little known sophist and Gazean grammarian, who wrote a sort of narrative zoological *Περιήγησις* (*Periegesis* probably in four books) on exotic quadrupeds, birds and snakes. The *Συλλογή* incorporates extensively all relevant chapters of the huge works by Aelian and we can assume that it also includes most if not all of Timotheus's text for the animals appearing in it, thus offering a reliable sample of the book. Indeed, a close comparison between Timotheus' summary (of *c.* 5,500 words) and the

34 See Kindstrand, "Manuel Philes' use of Aelian's *De natura animalium* in his *De animalium proprietate*."

35 Lemerle "L'encyclopédisme à Byzance," p. 607.

36 See e.g. *Aristophanis Historia Animalium Epitome*, ed. S. Lambros, A 7, p. 2, l. 13–15: "Are 'provided with two rows of teeth' (*amphodonta*) the man, the horse, the donkey, the elephant and all animals that do not have alternate teeth. These animals have the characteristic of having fat and not suet."

37 It was edited by Haupt in 1869 (*Excerpta ex Timothei Gazaei libris de Animalibus*) and translated in 1949 by Bodenheimer/Rabinowitz (*Timotheus of Gaza. On animals*).

excerpts of the *Συλλογή* shows that all the information is preserved in our compilation. Here is a typical passage from the chapter on the cat:

> This animal has eyes that are in sympathy with the moon and cats show to everyone in which phase of its cycle it is: whether it is waxing or waning, when it tapers its horn, the eye of the animal simultaneously tapers off, which forms a narrower curved line on both sides; when, on the contrary, the moon is full and forms a perfect circle, combining its two crescents, then the eye also appears in the same way as having a circular-shaped structure.[38]

As far as we can judge from the *Excerpta*,[39] the animal portraits displayed in the original work, where they were arranged in a loose order, focus on psycho-ethological characteristics that define the identity or *phusis* of the animal. In this innovative and rich *ekphrasis*, Timotheus does not follow any precise source,[40] but many parallels can be found with Aelian, Oppian, and the *Cyranides*,[41] and even the *Physiologus* (on this text, see below). Timotheus shows a predilection for the accurate description of behaviour (*ethos*), for local varieties and, like Aelian, for moralizing anecdotes. Special emphasis is also laid on the topic of animal sympathy and antipathy, as well as on magical and therapeutic properties and uses of animals, popularized by the Pseudo-Democritan tradition (Bolus, Nepualius, Pamphilus …) and by the *Cyranides*. The scholarly culture of the author is expressed both by philological remarks[42] and by a pronounced taste for myths of metamorphoses: Dionysus' nursed by panthers,[43] Lycaon turned into a wolf,[44] Phineus turned into a mole.[45] He provides us with original data on carpets made with camel hair,[46] on a species of flying mouse[47] and on an Indian treatment of the corpses of mice.[48] Remarkably, Timotheus,

38 *Aristophanis Historia Animalium Epitome*, ed. S. Lambros, B 305, p. 98, l. 29–99, l.3.

39 For a thorough analysis of the book, see Zucker, "Approche structurelle et phraséologique de l'ouvrage de Timothée de Gaza *Sur les animaux*."

40 See Zumbo, *Timoteo di Gaza*, pp. 425–26.

41 A Greek text in five books, mentioning magical and curative powers of animals, plants (and some stones). See Kamaikis, *Die Kyraniden* (ed.).

42 *Aristophanis Historia Animalium Epitome*, ed. S. Lambros, B 235, p. 89, l. 5–7; B 507, p. 131, l. 12–14; B 517, p. 132, l. 7–9.

43 *Ibidem*, B 266, p. 93, l. 21–24.

44 *Ibidem*, B 237, p. 89, l. 14–17.

45 *Ibidem*, B 423, p. 118, l. 8–11.

46 *Ibidem*, B 474, p. 125, l. 5–27.

47 *Ibidem*, B 386, p. 111, l. 25.

48 *Ibidem*, B 365, p. 108, l. 15–23.

who was probably Christian, writes on animals as if he were a Pagan and never touches on theological perspectives; like Tatian (2nd century), author of a book *On Animals*, lost but mentioned in his *Oratio ad Graecos* (*Address to the Greeks*),[49] he is convinced that animals are not deprived of *logos*.[50] In this way, he takes an original position on a major issue among Greek philosophical schools and one that Christian authors decided in a quite unanimous way. Indeed, with a few reservations (concerning Nemesius or Philopon for example), they generally follow the Jewish conception according to which the animal is subject to human interests, projects and desires.[51] In any case, this is perfectly in line with the Stoic's dominant doctrine, who, contrary to Pythagoricians, Epicurian or Cynics, fiercely deny that animals are reasoning beings, arguing instead that they are operated upon by God's providence and will. This issue was in fact mainly sociological and cultural, as clearly stated by Plutarch, who emphasizes that if animals are λογικοί (possessing reason), justice does not exist anymore (since men are unfair to them) and men cannot live anymore (since sacrifices and diets rely on them).[52] The prestige and circulation of Timotheus' book is discovered in the work of later Byzantine authors, such as John Tzetzes who mentions him along with Aelian, Oppian and Leonidas of Byzantium (2nd–1st century BCE) among zoological writers,[53] but also by numerous echoes and quotations in Arabic literature under the name of "Atmûniyûs the Wise."[54] Arabic authors never refer to Byzantine authors on zoological issues, except for Timotheus, who stands as a major source for al-Marwazī's book *Nature of Animals* (12th century) and the anonymous *Treatise on the Attributes of Animals* (13th century) derived from—and erroneously ascribed to—Ibn Bukhtīshūʿ; his work was probably used by many other scholars (such as al-Baladī, al-Rāzī, or al-Qalānisī).[55]

## 4 *Physiologus* and Hexaemeral Literature

### 4.1 *Physiologus*

Yet the most typical and significant text of Byzantine zoological production is of a totally different kind. The *Physiologus*, which has a richer manuscript

49 *Oratio ad Graecos*, ed. Goodspeed, 15.1.7–2.5.
50 See *Timotheus' epitome* c. 50, ed. Haupt, p. 27, l. 6–10.
51 See Gen. 1:26.
52 See Plutarch, *De sollertia animalium*, ed. Bouffartigue, 963F–964C.
53 See *Chiliades*, 4.166, ed. Leone, nº 128.
54 See Kruk, "Timotheus of Gaza's On Animals in the Arabic Tradition."
55 See Contadini, *A World of Beasts*, p. 49.

tradition by far (a hundred manuscripts, and a full third of them prior to the 15th century)[56] better typifies how Byzantines generally referred to animals and made intellectual use of them.[57] This work of an unknown author stands as the first Christian *bestiary* and initially consists (in the "first recension") of a collection of chapters (around fifty), unequal in size, but generally quite short (between six lines and two pages), arranged without any fixed order, and essentially dealing with animals (though also including five stones and two trees). Every chapter is devoted to a specific animal in a naturalistic *and* spiritual perspective (lion, pelican, hedgehog, unicorn…) with a roughly regular binary structure: the first part is descriptive and presents an animal (or another natural being) through a characteristic trait, or rather a particular traditional behaviour, dubbed as his "nature" (*phusis*); the second is a Christian interpretation, decoding the natural property as a theological lesson or a moral exhortation addressed to the reader to do good and avoid evil. The *Physiologus*, probably written in Egypt (or Syria) between the 2nd and the 4th century, spread around and evolved extensively throughout the period. Indeed, it would be more properly called an open literary frame than a static text, since his name is given to a wide array of writings sharing a similar structure and purpose but with highly varying content. It was very soon translated and adapted into all ancient literary languages (Arabic, Armenian, Coptic, Ethiopian, Georgian, Latin, Syriac) and later into Old English, Icelandic, Slavic, etc., giving rise to Western medieval bestiaries.[58] Surprisingly enough, despite its considerable importance in Western culture, the Greek version remains untranslated into modern English. Traditionally four different Greek collections (named "recensions") or stages are distinguished,[59] but their respective dating is much disputed: the second collection, known as the "Byzantine collection" can be dated from its linguistic features to the 9th–11th century, although some date it back to the 5th century![60] The third one, named "Pseudo-Basilean," was composed between the 10th and the 12th century. The last one, which is a political poem in verse, unlike the previous collections that are all in prose, was written during the 13th century, and very close in content to the so-called Byzantine

56 See the recent inventory of the manuscripts in Lazaris, *Le Physiologus grec*, t. 1.

57 See Lazaris, *Le Physiologus grec*, t. 1.

58 Note that there is apparently no Hebrew translation or Jewish use of the book. On Oriental and Latin translations of the *Physiologus* an International Conference has been recently organized in Paris by A. Dorofeeva, S. Lazaris, C. Macé and A. Zucker ("The Physiologus between East and West, June, 2017). See *RursuSpicae* 2 (<https://journals.openedition.org/rursuspicae/>).

59 See Sbordone, *Physiologi graeci singulas variarum aetatum recensiones*, p. i–cxix.

60 See on the datation Lazaris, "Un nouveau manuscrit illustré du *Physiologus* grec," 2017.

collection. Difficulty in dating the three major collections (1–3) is increased by the great plasticity of the text and the substantial variations in the manuscript tradition of each collection. All of them are clearly connected to each other and, except the second collection, they mix "real" animals with some "mythical" ones, such as onocentaur, phoenix, water-horse or unicorn—which is depicted as a combination of lamb, rhinoceros and horse. Mostly focussed on birds, quadrupeds and snakes, they include a large proportion of Afro-Asiatic fauna (lion, panther, crocodile, onager, elephant, tiger…). The portrait of each animal, developed generally in a single nature but sometimes extended through up to four different characteristics (for the viper), is occasionally introduced by a scriptural quotation and gives rise to an allegorical interpretation often different from one collection to another. The main religious issues are that animals embody resurrection, passion, chastity, fasting, and the struggle against evil. As the subtitle of an ancient manuscript indicates, the core of the text is to illustrate "the economy of the incarnation," in other words, the mystery of the incarnation of God and the foundation of the Christian doctrine.[61] Here, as a sample, is the chapter on the pelican:

> [King] David says: "I am like a pelican of the wilderness." The Physiologus said that the pelican particularly loves its offspring. Thus, when he has given birth to chicks and they are a little grown up, the latter spit in the face of their parents. Parents slap their children and kill them. Afterwards, the parents suffer in their bowels and mourn for their dead children [while staring at them] for three days. On the third day, the mother hits its own flanks and her blood drops on the dead bodies of the chicks and wakes them up. Likewise, the Lord said in Isaiah, "I have begotten sons, and have raised them up, but they have repelled me." The Creator of all creation has begotten us and we spat in his face. How did we spit in his face? We loved the creation instead of the Creator. So the Saviour ascended the heights of the cross, opened his side, and made drip blood and water for salvation and eternal life: the blood, because of him who said "Having taken the cup, he gave thanks"; water, because of conversion baptism.[62]

As is apparent in this chapter, the conventional title given to the book (*Physiologus*) is in fact the name of an alleged teacher of natural science. There is yet no identifiable and unique source for the naturalistic components of the

61 Milan, Biblioteca Ambrosiana, A 45 sup, fol. 97v (ms M in Sbordone).
62 *Physiologus. Prima redactio*, ed. Sbordone, pp. 16–19.

chapters. The name of Basil of Caesarea often crops up in the tradition as a candidate, but only some of the content has parallels in his *Homiliae in Hexaemeron*. Despite some clear-cut statements criticizing allegorical excesses,[63] Basil did not radically condemn this kind of exegesis[64] and he is named in the third collection as the authorized interpreter of the natural data, which is regarded as God's handiwork. Following the exposition of animal nature, in all chapters in this collection the spiritual commentary begins with the words: "Saint Basil says…." The general programme is made clear in the first chapter: "Basil the Great interpreted allegorically the natures of the animals of the very learned Solomon and attributed to them a spiritual value."[65] The whole text of the first collection has even been ascribed to him, but also, indeed, to Peter of Alexandria († 311), Athanasius of Alexandria (*c.* 298–373), Epiphanius of Salamis (*c.* 315–403), John Chrysostom (*c.* 345–407)…. This book is actually at the crossroads of five traditions: Graeco-roman zoology, Egyptian esotericism, Jewish mysticism, Alexandrian exegesis and the Christian theology of salvation. He draws both content and method from Biblical texts (especially Proverbs, Psalms, Isaiah, Song of Songs…), but the process also echoes the practice of Aelian, who often concludes his notices by a parallel with man.[66] Because of interpolations in the late preserved manuscripts, zoological sources are difficult to establish precisely, as, for example, in the chapter on the elephant, which now contains an entire paragraph imported word for word from a homily of Basil and inserted into the text,[67] or in the chapter on pearl in which a late copyist introduced a quotation borrowed from a homily by John Damascene (7th–8th century).[68] Zoological information is ultimately stock, very limited and clearly biased to match doctrinal or moral topics. Few manuscripts retain only the natural section, which represents less than half of the text in the first collection (*c.* 4,000/10,000 words), but the *Physiologus* was likely not intended to stand as a naturalist handbook and generally not regarded as such.[69] In this ongoing exegetical workshop and depository of *exempla* Christian writers and preachers could find spectacular illustrations and symbols for their catechetical, apologetic or homiletical discourses. This text had a wide

63 See *Homiliae in Hexaemeron*, ed. Giet, 2.5 (40B), p. 162; 3.9 (73C–76A), pp. 234–36; 9.1 (188 BCE), pp. 478–80.

64 Lim, "The Politics of Interpretation in Basil of Caesarea's Hexaemeron."

65 *Physiologus. Tertia redactio*, ed. Sbordone, p. 259, l. 11–13.

66 French, *Ancient Natural History*, p. 226; see also Rowland, "The Relationship of St. Basil's *Hexaemeron* to the *Physiologus*."

67 Chap. 43, in Offermanns, *Der Physiologos nach den Handschriften M und G*, p. 139.

68 Chap. 44b, in *Physiologus. Prima redactio*, ed. Sbordone, p. 137, l. 7–8.

69 See contra Lazaris, *Le Physiologus grec*.

influence on all the Greek and Latin patristic literature, and chiefly impacted the homilies on Creation (*Hexaemeron*). This influence, however, is clandestine, since it is almost never explicitly disclosed by ancient or medieval scholars.

### 4.2 *Hexaemeral Literature*

Yet, by far the most official and continuous tradition of zoological accounts is the 'Hexaemeral' literature, i.e. the Bible commentaries devoted to the creation of the 5th and 6th days. The Scriptures do not provide any theoretical information on animals, which are generally casually mentioned, often as metaphors or symbolic parallels, or listed as forbidden or permitted food (as in Lev. 11 or Deut. 14). However, the first chapter of Genesis, even if it briefly reports the process of creation, provides an opportunity to elaborate on the diversity of animals and the wisdom of God imprinted on their bodies and their behaviours, "since God put a clear trace of his wisdom in every of them."[70] In the history of the Greek *Commentaries on Hexaemeron*, which dates back to Philo of Alexandria (*De opificio mundi*) and includes works by Theophilus of Antioch († 188), Hippolytus of Rome (170–235) and Origen (185–253),[71] Basil of Caesarea plays a fundamental role, and he remains the major reference during the whole Byzantine era. His three homilies on the Creation,[72] written and delivered in the second half of the 4th century (*c.* 377), not only testify to zoological classical knowledge but constitute a species of funnel. The bishop of Caesarea draws from many ancient sources, including Aristotle's *Historia Animalium* with which his text shows numerous obvious parallels or literal borrowings, he probably had access to it through secondary literature and summaries. He includes Aristotelian discussion on the breathing of fish, and seems familiar with the elaborated taxonomic classification, commenting very broadly on some zoological issues. He deals in general terms with "fish" (except crabs and octopuses), but he goes into details when addressing "birds" (crane, swallow, stork, turtle…and bats and bees) and quadrupeds. While listing different ethological characteristics of animals, all documented in the earlier literature, he is explicitly intent on showing the wonderful anatomical variety of animals and their incredible skills. But his admiration for the natural θαύματα (marvels)[73] ultimately refers back to the Creator, and appears as an endpoint—not a starting point, as in Aristotelian epistemology. This restrictive viewpoint (not interested in investigating the natural and physiological causes), which he

70 Basil, *Homiliae in Hexaemeron* 7.5 (157C), ed. Giet, p. 414.

71 See Robbins, *The hexaemeral literature*, pp. 24–41.

72 Basil, *Homiliae in Hexaemeron* 7 to 9, ed. Giet, pp. 391–522 (*c.* 11,000 words).

73 See *Homiliae in Hexaemeron*, ed. Giet, esp. 7.6 (161A), p. 420; 8.7 (181C), p. 466; 8.7 (184A), p. 468; 8.8 (184C), p. 472; 8.8 (188A), p. 476; 9.3 (196A), p. 494.

shares with his friend Gregory of Nazianzus in a similar context,[74] is common to the entire hexaemeral tradition, and not far from the perspective of the first Arabic naturalist Al-Jāhiz, whose purpose in the seven books of his *Book of Animals* is to demonstrate the power and wisdom of God through the observation of animals. The idiom *κατὰ γένος* (according to its kind), occurring in the text,[75] prompted all further commentators to focus on their distinctive peculiarities (*ἰδιώματα*),[76] which are in accordance with divine providence. As is demonstrated by his selection, Basil pays special attention to animal self-medication (bear, fox, hedgehog, snake) and meteorological awareness (sheep, cow, hedgehog), ascribing to some of them (cranes, vultures…) a consciousness that borders on "rational intelligence."[77] The final purpose of Basil, as dictated by the genre of this homily, is to depict as moral *exempla* the various animal situations and behaviour, and to encourage his brethren to follow these natural models, or conversely to identify moral danger and avoid falling into it: "But I would that you should at once rival the crab in cunning and industry, and abstain from harming your neighbour; this animal is the image of him who craftily approaches his brother."[78]

The Pseudo-Eustathius' *Commentarius in Hexaemeron*, erroneously ascribed to Eustathius of Antioch and probably written soon after in the late 4th century or early 5th century, offers richer zoological information and quite a different aspect. It is nothing but a compilation of identifiable excerpts[79] (generally short but up to 120 words long), ultimately from various sources (including passages drawn from novels such Achille Tatius' *Leucippe and Clitophon* for a description of crocodile), but probably already put together in compilations, especially for the 15 zoological pages commenting on the 5th and 6th days. The main difference from Basil's text, on which it largely relies, is that the short zoological chapters, which border on the sensational, through the hackneyed characteristics of 67 animals from sawfish to cicada (5th day) and from lion to flee (6th day), are no longer embedded in theological examinations or moral comments, but given almost all in a row in a purely naturalistic way. Intertwining numerous sections from the *Physiologus* to Basilean segments, in the

74 See Gregory of Nazianz, *De Theologia* (*Second theological Oration* = Or. 28), ed. Barbel, 23–25.

75 Gen. 1.20, 24, 25.

76 Basil, *Homiliae in Hexaemeron*, ed. Giet, 8.5 (176A), p. 452; Pseudo-Eustathius, *Hexaemeron*, ed. Migne, *Patrologia Graeca*, 18, p. 724.42.

77 See *Homiliae in Hexaemeron*, ed. Giet, 9.5 (201C), p. 508; 8.5 (176B), p. 452; 8.7 (181C), p. 468.

78 *Homiliae in Hexaemeron*, ed. Giet, 7.3 (153B), p. 406.

79 See Zoepfl, *Der Kommentar des Pseudo-Eustathios*, p. 17.

zoological section this *Commentary* provides us with a scrapbook of portraits, with the argument that "the diverse nature of animals gives the knowledge of divine Providence."[80] Surprisingly, this "catalogue" of animals, broken only by one page praising God's πρόνοια (Providence) when introducing the 6th day, is entirely obliterated in the Ethiopian and Arabic versions of the text inserted in the *Adam book*.[81]

All remaining hexaemeral texts, though generally relying on Basil for the section on animals, are not in the same vein and, with the exception of George of Pisidia, do not offer as much consideration of zoological material. Procopius of Gaza (5th–6th century), who also drew upon Philo, Origen, Basil, Gregory of Nyssa, and Didymus the Blind (*c.* 313–398) for his commentary, has very little to say on animals and deals with the question in four short pages, after arguing that birds were created the same day as fish because they are born in water and mostly get their food from it [*sic*], then reproducing some general comments taken from Basil including a critique of allegorical interpretations.

John Philoponus' *De opificio mundi* (*On the Creation of the World*, 6th century) tackles the question in a more philosophical way and draws on ancient scholars, claiming to prove the scientific validity of Biblical statements on nature,[82] and discussing Gen. 1 through a series of questions such as "why land-animals come after fish in the creation," "why water-animals and birds are created together," or "whether animal souls perish with the body."[83] In the course of his arguments, he mentions, in passing, the octopus and the *adonis* (flying fish) as amphibians and explains the etymology and meaning of ἕρπετα, used for water animals as well as the ancient use of θηρία (for animals) relying on biblical occurrences.[84] He seems to be concerned with the issue of animal intelligence, pointing out the intellectual gradation from plant to man and the superiority of land animals over other animals and inserts, in an unexpected way, a long anecdote from the Paradoxographer Phlegon on the extraordinary devotion of the hound of Lysimachos of Macedonia to its master.[85]

The *Hexaemeron* or *Cosmourgia* by George of Pisidia (7th century), who also wrote on historical and doctrinal issues, is not strictly speaking a commentary, but an elaborate poetic hymn of 1910 verses. Especially influenced by the two Cappadocians Gregory of Nazianzus and Basil, George does not quote nor

80 *PG* 18, 757D.
81 See Trumpp, *Das Hexaëmeron des Pseudo-Epiphanius*.
82 John Philoponus, *De Opificio mundi*, ed. Reichardt, p. 205, l. 6–10.
83 See respectively *De Opificio mundi*, ed. Reichardt, chap. 1, p. 205; chap. 3, p. 212–3; chap. 13, p. 227.
84 See respectively *De Opificio mundi*, ed. Reichardt, chap. 6, p. 217; chap. 12, pp. 225–26.
85 *De Opificio mundi*, ed. Reichardt, p. 208, l. 22–209, l. 15.

follow the first chapter of Genesis but repeatedly glorifies the Creator with an ecstatic litany of rhetorical questions emphasizing all constituents of the natural world. In the zoological section that lists 47 animals (about half of which do not occur either in Basil's or in Pseudo-Eustathius' work), most of the animal characteristics of the *Physiologus* are recycled ones.[86] George of Pisidia gives a great variety of (conventional) zoological details, and uses a rich medical terminology (probably partly borrowed directly from Galen).[87] He explains in a quite innovative manner the reproduction of eels (v. 1030–38), saying that this fish, which has no womb or semen, rubs itself against rocks. Then the fragments of skin that are torn from it become its offspring. This is a way of confirming the truth of the Biblical account on the origin of Eve from a rib (or the side) of Adam. As a matter of fact, George's aim is not only to praise the marvels of the creation and highlight the natural science God expressed through animals—the ibis being wiser than Galen (v. 1129)—, but to prove the mysteries of the Christian faith. The parthenogenesis of the vulture demonstrates the truth of the conception of the Virgin (v. 1149–53), the spider weaving its web without pre-existing matter witnesses that the material world needs a cause and comes second (v. 1393–6), and the silkworm which rises from the grave-like cocoon wherein it lays substantiates the possibility of resurrection (1293–1317), as well as the swallow which somehow arises in springtime as did Christ (1318–55). George's iambic composition, which is reminiscent, albeit on a larger scale, of poems by William Blake such as "The Tiger," similarly offers a gallery of natural of mystical emblems.

In a more concise and less inspired way, Anastasius of Sinai (7th century), half a century later, offers, in his *Hexaemeron*, an allegorical reading of the creation (its σύμβολα and αἰνίγματα).[88] Relying on a Christian perspective he confines himself to simplistic comments on animals, identifying marine monsters with apostles, birds with the baptized, fish with sinners,[89] etc. He tackles the question of the blessing of God imparted exclusively to fish and men in the Genesis account arguing that, according to fishing specialists, fish conceived without semen from the (spirit of the) wind.[90] Cosmas of Jerusalem (vel Cosmas of Maïouma), foster-brother of John of Damascus (8th century) also testifies to the spreading of naturalistic knowledge beyond the boundaries of

86 *In Hexaemeron*, ed. Gonnelli, v. 926–1350. See Tartaglia, "L'excursus zoologico dell' Esamerone di Giorgio di Pisidia."

87 George of Pisidia calls God the "Galen of the universe, physician of the souls" (v. 1345–6).

88 *In Hexaemeron*, ed. Baggarly/Kuehn, 5.8.1, l. 374.

89 *In Hexaemeron*, ed. Baggarly/Kuehn, 5.6.2, l. 282; 5.7.3, l. 362.

90 *In Hexaemeron*, ed. Baggarly/Kuehn, 5.1.3.

hexaemeral commentaries.[91] Commenting on the works of Gregorius of Nazianz and especially the *Carmina de se ipso*,[92] he discusses and expands the allusions made by Gregorius to various animals in many chapters that echo both the *Physiologus* and Basil's *Homiliae in Hexaemeron* on sepia, mule, deer, generative stones, turtle, amphibians, asp, phoenix, remora, turtle-dove, crow, burning fish, lodestone, diamond, stone-shining-in-the-water, starling, kites, parrot, bear, lion, elephant, crabs, deer, bee, cow, swallow, crow, dogs, lioness, dolphin, eagle, viper, cicada, eagle, *dipsas*, flea, chameleon, jackdaw, and wasp.

In this overview of zoological accounts in hexaemeral literature, Michael Glykas' *Annales* (vel *Chronicle of events from the creation of the world to the death of Alexius I Comnenus*, 12th century) deserves a brief mention. His elaborate account of creation contains abundant information on animals[93] and the large section devoted to the 5th and 6th days has been sometimes transmitted as a separate text and even entitled once "Physiologus" by a scribe.[94] In his didactic *Annales* (*Chronicles*) his first remark is addressed to verses in Genesis where it treats of the fifth day explaining why fish die when removed from water.[95] This problem is not one suggested by the Scriptures. Instead it is an Aristotelian question (as the following remark on fish denture and absence of rumination, with the traditional exception of the parrot-wrasse) commented on in *De respiratione*, and the explanations given by Glykas come directly from Basil's *Hexaemeron*. Generally speaking, all comments on the creation of animals are frequently derived *verbatim* from the Greek tradition, but Glykas seems to have had recourse to a wide array of sources, among which are Basil, Anastasius, Aelian, the *Physiologus*, Plutarch, Nicander, Pseudo-Alexander's *Problemata*, Theophylact Simocatta, etc. In his compilation he scrupulously respects the order of the segments he draws on and often the phraseology itself in a work that originally combines the traditions we distinguished (Peripatetic tradition, Physiologus, Hexaemeron, ….) Neophytus of Cyprus writes the last commentary of the period (*Commentarius in Hexaemeron Genesim*) at the turn of the 13th century. He is deliberately terse about the 5th and 6th days, just providing the reader with a list of some marine monsters (κήτη) and birds, and barely listing eleven quadrupeds and beasts including "mythical" creatures (*onocentaur*, *monoceros*, *basiliskos*, *kerberos*).

91 *PG* 38, col. 631–70. *Commentarius de physicis rebus*.
92 *PG* 37, col. 969.4 sq.
93 See Sarton, *A history of science* 2.1, p. 133.
94 *Annales*, ed. Bekker, pp. 65–136. See Sbordone, "ΦΥΣΙΟΛΟΓΙΑ Parigina degli Annales di Michael Glycas."
95 *Annales*, ed. Bekker, p. 65.

## 5 Geographical Tradition and Animal *Ekphraseis*

The tendency to restrict zoological knowledge to individual portraits focussed on a small number of typical features, strongly influenced by the collections of *Mirabilia* (compilations of marvels), goes beyond the *Physiologus* and the boundaries of hexaemeral literature. Many such spectacular depictions of animals can be found in historical and geographical works, but without special concern in their respect for biological issues or even anthropozoological relations. Contemporary anecdotes are yet relatively rare, such as the report provided by Procopius of Caesarea (6th century) about a 44 ft. long killer whale "which the Byzantines called Porphyrius. It sowed terror for a long time in the region before being blocked in the mud. It was then dismembered and eaten fresh or in pickles."[96] As was already the case in Herodotus' paradigmatic and influential book on Egypt it is not surprising that exotic animals (especially elephants and giraffes) are most prominent in this context. However, very little new information appears in the texts that have come down to us on the fauna of distant countries. The fragment of the lost *Geography* by Cosmas Indicopleustes (6th century), known as book XI (chap. 1–12) of the *Topographia Christiana*, is an exception. Apart from briefly commenting on the method of killing seals, dolphins and turtle, and the nature of their flesh, Cosmas describes a dozen animals, mostly Egyptian/Ethiopian (rhinoceros, buffalo, giraffe, hippopotamus) or Asiatic (yak and musk-deer from Tibet, the mysterious pig-deer—a babirusa?). The zoological identification of animal's names, especially for small ones (like arthropods), is a general problem: uncertainty abounds, and the Byzantine *Lexica*, which contain a significant number of entries on animals, are too scanty and vague to be helpful. Most of them were already well known to Greeks since the expedition of Alexander to the East and the numerous reports that followed (Onesicritus, Nearchus, Callisthenes, etc.), but Cosmas included personal sketches of animals, and plants as well, in his book.[97] Since he probably never travelled to India,[98] these pictures were probably made mostly from iconographic sources. After describing the rhinoceros—"unicorn"—he claims to have personally seen one "from a good distance" and

96 *De Bellis*, ed. Dewing, 7.29.9–2.

97 Cosmas, *Topographia christiana*, ed. Wolska-Conus, 11.2, 4 and 7, p. 317, 321, 327. See Christides, "The sources of Cosmas Indicopleustes' miniatures of animals." For the drawings in the ms. Florence, Biblioteca medicea Laurenziana, Plut. 9.28 (fols. 267r–272v), see plates LV-LIX in Anderson, *The Christian Topography*.

98 Wolska-Conus, "Recherches sur la 'Topographie chrétienne' de Cosmas Indicopleustès," pp. 4–9.

to have made its portrait from a stuffed model in the royal palace.[99] The illustrated books, together with the rich tradition of mural paintings and mosaics, provided enough models for literary ekphraseis, as witnessed by the depictions of Philostorgius (5th century). In a fragment related to his *Historia Ecclesiastica* (*Church History*) he himself describes, from a sculpture seen in Constantinople, an atypical unicorn, with a dragon's head, a little twisted black horn, a mouth full of beard and the body of a deer.[100] He also claims that a kind of ape called "Pan" was sent to the emperor of Constantinople by the king of India,[101] and mentions an exceptional variety of monkey, along with a zebra (wild ass) very carefully described. This probably also came from a picture.[102]

Two main authors of the late Byzantine empire, both poets and connected with this narrative tradition, engaged more intensively with the description of animals. John Tzetzes (12th century), who also wrote lost commentaries on Oppian's poem on fishing, and on Nicander's *Theriaca* and *Alexipharmaca*, occasionally deals with animal anecdotes in his long poetic *Chiliades* (*Book of Histories*). This is divided into chapters, with a continuous section in books 3 and 4.[103] The poet draws his information from many ancient authors whom he follows closely, and who are thus generally easy to trace, such as Diodorus (chap. 113), Arrian (chap. 115), Herodotus (chap. 116), Oppian (chap. 117), Homer (chap. 118), etc. Still, his chief source is clearly Aelian (chap. 117, 128–32, 134–135), whom he paraphrases with delight, and his most recent one Timotheus; he pays explicit tribute to both of them.[104] He is especially interested in tales of wonder (such as the exceptional silence of the Seriphian frogs) and mythical stories (such as the origin of the cicadas),[105] and does not seem to make use of the *Physiologus* or more generally of Christian literature.

This indifference to Byzantine literature and theological issues also characterizes the work of Manuel Philes, in the beginning of the 14th century. A disciple of Pachymeres (1242–1310) and friend of Maximus Planudes (*c.* 1258–1308), as well as a court poet (who constantly—i.e. more than 50 times!—calls on the emperor in his poem), he wrote an iambic poem of 2015 verses, divided into 119 chapters of uneven size (from 3 to 105 verses) and named after Aelian's

99 Cosmas, *Topographia christiana*, ed. Wolska-Conus, 11.1–2, p. 317.
100 Philostorgius, *Fragmentum apud Photium*, ed. Bleckmann/Stein, 3.11.13–18.
101 Philostorgius, *Fragmentum apud Photium*, ed. Bleckmann/Stein, 9.19.182.
102 Philostorgius, *Fragmentum apud Photium*, ed. Bleckmann/Stein, 3.11.65–71. These popular descriptions are copied by Xanthopoulos, in his *Historia ecclesiastica* (*Eclesiastical history*) at the turn of the 14th century (*PG* 146, 9.19, col. 301–5).
103 See Tzetzes, *Chiliades*, ed. Leone, 3, chap. 113–4, chap. 135.
104 See Tzetzes, *Chiliades*, ed. Leone, 4, chap. 128.
105 See Tzetzes, *Chiliades*, ed. Leone, 8, respectively chap. 167 and 166.

masterpiece *De proprietate animalium* (*On characteristics of animals*), as well as several shorter zoological *ekphraseis* (*On elephant*, *On silkworm*, *On ostrich*, *On vulture…*). The dedicatory letter, added by Arsenius Apostolius (*c.* 1468–1538), bishop of Monemvasia, insists on the moral teaching provided by the book, but this perspective is misleading. Philes does not insist on this tropical use or intend to impart religious guidance, nor does he rely on Christian literature. The Creation is a wonder (τέρας) but in a very classical sense (astounding but not proving divine mystery and providence), and all his knowledge comes explicitly from the Ancients (παλαιοί), namely the Pagan writers.[106] He himself draws most of his information from Aelian, mainly adopting his point of view and repeatedly addressing the question of the intelligence of animals as well as tackling morally related issues.[107] Philes' *On characteristics of animals* ultimately appears as a poetic paraphrase of Aelian's excerpts, which even adopts similar terminology in a metrical version.[108] There is no convincing evidence of even a marginal use of the *Physiologus* or of Timotheus of Gaza and no other established sources, apart from Pseudo-Aristotelian *Mirabilia*.[109] Some chapters may derive more or less directly from Oppian and from George of Pisidia, but no explicit parallels have been shown by any systematic comparative inquiry. In this poem (as in its model) there is no place for personal experience and even the occasional moralizations are hackneyed and overused. In the manner of Aelian, Philes contrasts animal natural skills and human medicine, pharmacopoeia, witchcraft and astrology. He conveys some medical remedies, especially against poisons (as the horn of the red-headed and white-haired onager, in chap. 43) and dwells on natural antipathies, animal antipathies, and substances used by animals against evil spells (chap. 31). Independently of this work, Philes was the author of the longest Greek description of the elephant (321 verses), ending with a long and fawning praise of the emperor (60 verses). He comments at length on elephant's anatomy, the way the offspring suckles from its mother (not with its trunk!), its diet, its erotic temper and the artistic skill in the devices elephants use to help one another. Apparently, most of the data come from Aelian, including the famous struggle with the Indian dragon—*Python molurus*?—, but could also come partly from iconography.

106 See *Versus iambici de proprietate animalium*, ed. Lehrs/Dübner, pref. v. 41–44.

107 Kindstrand, "Manuel Philes' use of Aelian's *De natura animalium* in his *De animalium proprietate*," pp. 119–39.

108 Note that the only example given by Caramico (*Le proprietà degli animali*, p. 24) of the conflation in Philes of a chapter of Aelian with another text is based on an error (πέψεως Hercher instead of ὄψεως).

109 The relation with Physiologus is suggested by Hunger, *Die hochsprachliche profane Literatur der Byzantiner II*, p. 267.

Indeed, he mentions pictures of the animal, as if he himself were describing one, insisting on the cartilaginous small shield-like ears (v. 67) which the elephant can spread or contract. He also devotes a noteworthy and well-informed double poem (103 verses and 43 verses) to the silkworm, whose importation to Byzantium around 550 AD is documented by Theophanes of Byzantium[110] and Procopius of Caesarea.[111] The classical description from Pausanias (2nd century)[112] already entailed remarkable details of its diet, its special habitat and breeding by the *Seres*, but also includes errors (on its aspect and lifespan). Philes carefully depicts its life course and the way the worm spits out the useless part of the sycamore leaves it greedily eats. He vividly details the starting point of the cocoon, the death of the caterpillar and its spectacular resurrection. The second part of the poem does not take up the hackneyed Christian exegesis on the proof of the resurrection (as in Basil or George of Pisidia), but calls for the reader to imitate the virtues of the worm, which is self-controlled, laborious, and productive.

## 6 Didactic Literature and Practical Treatises

We might expect technical texts to be more open to fresh information and keep pace with contemporary changes and innovations, but these texts are conservative and, incidentally, fairly rare. The didactic zoological literature (husbandry, hunting, fishing, toxicology), either in verse (Nicander, Virgil) or in prose (Xenophon, Varro) does not outlive antiquity. Until the Palaiologan "renaissance" we cannot trace a single text that significantly sustains the bright Alexandrine tradition. The five major poems on venomous animals (Nicander, *Alexipharmaca*, *Theriaca*), fishing (Oppian, *Halieutica*) and hunting (Oppian, *Cynegetica*; Dionysius of Philadelphia, *Ixeutica*) are transposed in the 4th–5th century CE into prosaic paraphrases, equal in length to the originals.[113] But these transcriptions, with the exception of the last mentioned, are ascribed to an unknown Eutecnius[114] and are based on a wide corpus of scholia. They are rhetorical exercises, more concerned with clarifying archaic terminology or mythological references than interpreting zoology. In addition, they show more interest in stylistic elaboration than in clear transcription and are not

110 Photius, *Library*, ed. Henry, cod. 64, 26a36–b6. Photius provides us with some accounts from the (lost) *Histories* of Theophanes.

111 Procopius, *De Bellis*, ed. Haury, 8.17.1–7.

112 *Graeciae Descriptio*, ed. Jones, 6.26.6, pp. 158–60.

113 Cf. Oppian, *Cynegetica* 13,583 words *vs* 13,800 for the *Paraphrase*.

114 Papathomopoulos, *Ανωνύμου Παράφρασις εις τὰ Διονυσίου Ἰξευτικά*, pp. xi–xii.

free from mistakes. Remarkably, after the 2nd century CE there is no new or reshaped toxicological treatise in the whole period under survey. The different treatises of this blossoming time (Galen, Aelius Promotus, Philumenus, *Alexipharmaca* of Pseudo-Dioscorides) are plundered and regurgitated as they had been received by late antique physicians in the 4th–7th century (Oribasius, Aetius of Amida, Paul of Ægina, anonym author [Pseudo-Dioscorides] of the *Theriaca*).[115] Nevertheless, some Byzantine manuscripts of ancient technical literature provide exceptional illustrations both in quality and rarity. Indeed, apart from the *Physiologus* tradition[116] and the case of the *Topographia christiana* of Cosmas, very few other Byzantine manuscripts offer animal miniatures.[117] The most ancient one is the *Codex Juliana Anicia* (now in Vienna[118]) produced in *c.* 512 with different treatises (Dioscorides, Oppian, Eutecnius, *Paraphrasis to Ixeutica*, *Anonymi medici Carmen de herbis*), where pictures of reptiles accompany Eutecnius' Paraphrase of *Theriaca*. Spectacular illustrations can also be found, for example, in the Constantinopolitan 10th-century manuscript of the Morgan Library (New York), codex M 652 (mainly with texts of Dioscorides and Eutecnius), including a hermit-crab (fol. 207v), a pill millipedes (fol. 209v), and an urchin with three pictures: exterior and interior views, and cross-section (fol. 214v), the latter being a *unicum* in the iconography.[119] A 14th–15th century codex with the Dioscorides' *De materia medica* (*On the natural products used for the preparation of medicine*) shows no less than 70 splendid birds, two dozen snakes and a plate of 14 arthropods.[120] Generally speaking the pictures are sometimes very "realistic," but sometimes they are

115 The date of Pseudo-Dioscorides' *Theriaca* is uncertain: in the late 7th or 8th century according to Touwaide ("L'authenticité et l'origine des deux traités de toxicologie attribués à Dioscoride," pp. 29–31), or *before* the 7th century, since Paul of Aegina would have used it, according to Lherminier ("Paul d'Egine, Galien et l'aspic de Cléopâtre," pp. 160–61).

116 See Bernabò et al., *Il Fisiologo di Smirne*.

117 See the excellent presentation with illustrations of Kádár, *Survivals of Greek zoological illuminations in Byzantine manuscripts*, pp. 37–135. We don't mention the controversial Artemidor papyrus and the collection of 38 sketches of animals drawn on the verso (probably of the 1st century CE), that are not linked to any special text (see Gallazzi et al., *Il papiro di Artemidoro*).

118 Vienna, Österreichische Nationalbibliothek, Med. Gr. 1.

119 Apart from its apograph Vat. Chigianus F. VII.159 (gr. 53). See Lazaris, "L'image paradigmatique: des *Schémas anatomiques* d'Aristote au *De Materia Medica* de Dioscoride," p. 136.

120 Vatican, Biblioteca Apostolica Vaticana, Chig. F. VII.159 (*gr.* 53), respectively fols. 228v–232v, 225r–227r and 227v.

not: for example scorpions may correctly have four pairs of legs,[121] either five or six,[122] or a number varying between 4, 5 or 6 pairs according to the species.[123] The question of "realism" in iconography is too thorny to be addressed here, but these variations, which in no way diminish the anatomical precision of certain images, cannot be regarded merely as signs of ignorance.

The mainstream production of practical or technical texts consists of thematic compilations carried out in the same spirit as the medical ones but with more rudimentary developments. The *Geoponica*, completed in *c.* 950 CE and dedicated to Constantine VII, is the only surviving book of the Byzantine era devoted to agriculture. Such a vital occupation surely gave rise to various anthologies and handbooks throughout this thousand-year period, in the wake of ancient didactic poetry (Hesiod, Nicander…) and Hellenistic and Roman prosaic literature on farming (Varro, Columella, Florentinus…). However, this loss is probably not fortuitous and most of the production of that time might have consisted of miscellanies and conventional compendiums. The *Geoponica* should be named *Excerpts on farming* to correspond with the title repeated many times in the book (περὶ γεωργίας ἐκλογῶν), given that the name "Geoponica" never actually appears. In reality the text is nothing more than a revised version and miscellany of material gathered in the 6th century by Cassianus Bassus in an anthology precisely entitled *Excerpts on farming*. In this "book" Bassus drew mostly on two compilations from the 4th century authors (Vindanius Anatolius and Didymus), who appear themselves, as far as we can judge from their recycled works, to be derivative writers as well. In this occupation (more than in any other) long traditions and tried and tested advice was accepted readily in order to maintain a reliable knowledge base. This new edition met a demand for a standard reference book during the encyclopedic turn of the Byzantine era.[124] It was written in a context of official encouragement to developing *latifundia*, after a long period of village growth and small peasant properties. A dedicatory proem, supposed to motivate the editorial undertaking, praises Constantine VII for "labouring in what is useful in life," restoring "all sciences and techniques," and supporting the three pillars of the state: army, religion and agriculture.[125] The proof of its success is demonstrated by the numerous extant manuscripts (more than 50) and the derivative translations in Latin and Syriac, then in Arabic. And yet, the book

121 Paris, Bibliothèque nationale de France, Suppl. Gr. 247, fols. 24r–25v (11th century), text of Nicander.

122 Bologna, Biblioteca Universitaria, Bonon. Univ. Gr. 3632.

123 Vienna, Med. Gr. 1, fols. 417r, 419r.

124 See Lemerle, *Le premier humanisme byzantin*, pp. 288–92.

125 *Geoponica*, ed. Beck, pref. 3–6, pp. 1–2.

is far from being new and far from possessing both the naturalistic knowledge widely dispensed or any intellectual firmness. It has none of the qualities of earlier writings on the same topics as, for example, Columella's *De re rustica* (*On Agriculture*) (2nd century) or even Palladius's work (4th century), which was largely derived from the former. The *Geoponica* explicitly stands as a collection of excerpts (*eklogai*) gathered from ancient Greek and Latin authors in which the compiler, at the top of the chapters, regularly reminds his reader of the source (paraphrased or quoted) of his information. Many sources referred to in the collection (and also listed at the beginning of the first book) are lost and the personality of many figures remains unclear. However, it seems that little or no information is to be found on authors later than the 6th century, i.e. the compilation carried out by Cassianus Bassus. The toponyms that occasionally appear mostly belong to Greece or Italy and Constantinople is named only once (12.1). This occurs in a chapter dedicated to "which plants have to be sown or planted each month at the latitude of Constantinople." This is probably the only original chapter added to Bassus. The last eight books of unequal length (13–20) successively deal with pests and vermin (book 13) and farm animals and game: poultry (book 14), bees (book 15), equids and camels (book 16), cattle (book 17), sheep and goats (book 18), dogs, swine and game (book 19), and fish (book 20). The "zoological" section of this huge collection (more than 500 pages) accounts for less than one quarter of it, each book being subdivided into numerous brief chapters, each dealing with an animal, one of its characteristics or a special topic (techniques for example of preventing snakes from visiting pigeon houses, cures for particular horse diseases, etc.). Although deprived of a programmatic prologue (apart from the dedicatory preface) or any overall methodology, the compilation covers human agricultural activities and livestock farming and apparently aims at providing farmers with practical instructions and handy information for farm management. Since breeding useful and/or fending off dangerous animals are the major issues in an agricultural context, the opening sentences (in books 14 and 16–19) claim to help managing animals in breeding (ἐπιμελεία), feeding (ἐκτροφή) and curing (θεραπεία). Most of the book indeed consists of medical instructions, charms and pieces of natural magic belonging to common folklore.[126] This is partly derived from the *Cestoi*, an encyclopedic scrapbook written by Julius Africanus in the 3rd century, and the work as a whole neither intends nor provides theoretical insights or specific animal knowledge. Whenever it comes to zoological characteristics it turns out to be frustrating, and never goes beyond commonplaces traditionally handed on from one writer on agriculture to another:

126 See Rose, "The folklore of the *Geoponica*."

a squill hung on the bellwether will repel wolves (18.17), as sure as a sprig of wild rue tied under a fowl's wing will protect it from cats (13.6, 14.15), and that hanging crab's claws around the neck protects from boar injuries (19.8). For a Thracian or Anatolian farmer it would prove rather unhelpful to learn that the only way to encourage lactation in goats is to tie dittany of Crete (*Origanum dictamnus*) onto their bellies (18.10). On the other hand, hardly any information is given on animal foodstuffs (apart from milk and salted meat). The *Geoponica* is mainly a jumble of conventional recipes scattered throughout the text. Book 20, for example, is devoted almost entirely to the composition of special, often complex concoctions to be used as baits for various species of fish. However, a few original pieces emerge such as the list of products that might curdle milk i.e. roasted salt, fig-tree juice or leaves, the hair of the artichoke, pepper and gizzard (18.19). In many of its aspects it appears close to the late antique collection of the *Cyranides* on the natural and magical properties of things, put together between the 4th and 8th centuries and significantly translated into Latin in 1169 for Manuel I Komnenos. As the compiler confesses in the preface, the *Geoponica* is *not only* written for practical purpose but also for "leisure" (τὰ περιττά) and the pleasure of eyes and ears (τέρψιν ὀφθαλμῶν καὶ ὀσφρήσεως).[127] The mixed aims of the author (probably of Cassianus Bassus called "Scholasticos") appear very clearly at the beginning of book 15. Before introducing a chapter on sympathies and antipathies between animals, allegedly drawn from Zoroaster he writes: "I strived indeed and made effort not only to gather useful information for the lovers of agriculture but also to make a suitable work apt to satisfy the lovers of literature." The text explains the meaning of τράχηλος (neck) and insists that αὐχήν refers to the back of the neck in man and to the upper part of the neck in animals, and δειρή to the front part of the neck in man and the lower part of the neck in animals because man is upright and animals are bent… (19.2)! Paradoxically, the book is often more intriguing when it misses its expected goal in setting out practical advice and provides misplaced information:

> On vultures. From Aristotle. Aristotle says vultures died under the scent of myrrh, and beetles under the scent of rose, because they live from bad odours. That vultures do note mate but fly instead facing the south wind and become pregnant, and give birth after three years […] Theophrastus and Aristotle say animals come to life not only through copulation but also through spontaneous generation and from decomposing earth. Animals and plants also change from one form to another, and they say

127 *Geoponica*, ed. Beck, pref. 9.

> indeed that caterpillar becomes a flying animal different from itself, the so-called butterfly and that the caterpillars of fig-trees change in beetles (κανθαρίς) and water-snake in viper, when the ponds dry.[128]

This uncontrolled patchwork of gallimaufry does not rely on Greek naturalists (Aristotle being quoted only five times in similar context) except occasionally through biased and fourth-hand information. Practical application, which in late antiquity was surely a principle concern for medicine and legal collections is less convincing here.

The work known as *Hippiatrica*, on veterinary medicine (see chapter 11 of this volume) is the second major compilation or miscellany of this time. It was gathered together in the mid-10th century, and parallels the Constantine *Collectanea*. Similarly, the *Hippiatrica* put together many pieces of different earlier texts, but the core belongs also to late antiquity even if it includes (in a single recension) scanty excerpts of the mid-10th century. Not surprisingly, these all share, with the *Geoponica*, common sources on land-farming such as Anatolius, a primary source for Cassianus Bassus, Hierocles, Pelagonius and the two pillars of the book: Theomnestus (4th century) and Apsyrtus (4th century), both being military officers. The corpus basically relies on a canonical list of seven main authors arranged in a regular order and its structure can be dated to the 5th century.[129] As McCabe points out on the content of the corpus: "worthy of note is the diversity of literary forms contained in the sources of the *Hippiatrica*: letters, incantations, proverbs, poetry, prooimia, reminiscences, medical definitions, instructions, and recipes."[130] It includes a list of horse breeds in alphabetical order from "Armenians" to "Hyrcanians"[131] and a smaller one ascribed to Anatolius,[132] but the bulk of the texts focuses on diseases, curing and practical treatments, with very little information on breeding horses. Connected books of horse medicine in different formats but with similar content were probably copied and used throughout the Byzantine period and all over the Mediterranean world. It is all the more surprising to notice how poorly these collections reflect the intense anthropozoological relations as evidenced by archaeological information, the Byzantines developed along with their technical skills.[133] We know indeed that the diet of Byzantine people

128 *Geoponica*, ed. Beck, 14.26, pp. 430–31 and 15.1, pp. 432–36.

129 Björck, *Apsyrtus, Julius Africanus et l'hippiatrique grecque*, pp. 9–12.

130 McCabe, *A Byzantine Encyclopaedia of Horse Medicine*, p. 14.

131 *Corpus hippiatricorum Graecorum II*, ed. Oder/Hoppe, pp. 121–24.

132 *Corpus hippiatricorum Graecorum I*, ed. Oder/Hoppe, p. 372.

133 See Anagnostakis et al., *Animals and environment in Byzantium*; Kroll, *Tiere im Byzantinischen Reich* and Kroll, "Animals in the Byzantine empire."

consisted of a considerable number of animal products and that they manufactured a considerable amount of pharmaceutical and household items, articles of dress, and other utensils out of animal parts.

We have lost the Constantine compilation on hunting (see above), probably drawn mainly from Arrian, Oppian and related texts, and there is actually no real *technical* text on hunting to be found in the remaining literature. From the Komnenian period, three *ekphraseis* (rhetorical descriptions) on hunting have been passed down to us, but they display limited zoological interest. Constantin Manasses (*c.* 1150), a chronicler and the author of romance and a life of Oppian, wrote a brief Ἔκφρασις ἁλώσεως σπίνων καὶ ἀκανθίδων (*Description of the catching of siskins and goldfinches*) (207 lines), a vivid account of an entertaining hunting party with a group of young bird-catchers under the lead of a grotesque old man. After confessing his incompetence in the matter, he describes various birds, some of whose names he allegedly learned on the spot, but whose skillful verbal depiction permits precise identification (e.g. the oriole). In his second *ekphrasis*, the Ἔκφρασις κυνηγεσίου γεράνων (*Description of a crane hunt*) (312 lines), Manasses first praises the hygienic benefit of hunting and briefly reports his personal experiences testifying to unexpected resources in animals, such as the "physiological" fact that "the lion cub while sleeping keeps the eyes of his soul open and sees."[134] He uses some rare ornithonyms (such as the ἀστρόγληνος, a hapax also occurring in the *Description of the catching of siskins*), and insists on the fact that some birds of prey have no (Greek) names (l. 96, 161). His report, steeped in Homeric reminiscences and military comparisons, is intended to feature a spectacular show,[135] and he depicts in great detail (20 lines) the Caucasian hawk of the emperor Manuel I Komnenos (1143–1181) and the cranes (11 lines)—along with the gloves, or the hunting manoeuvres. A third *ekphrasis* of the 12th century authored by Constantine Pantechnes' Ἔκφρασις κυνηγεσίου περδίκων καὶ λαγωῶν (*Description of the hunting of partridges and hares*) describes a hunt whose products were intended to be served to the imperial table, conducted with hounds, falcons, and tame leopards probably in Thrace. He provides us with considerable detail on the handling of the ounce when it has captured the prey, and on the behaviour of the trainer.

Real treatises on falconry, despite the emperors' taste as witnessed by Manasses, only appear at the beginning of the 15th century, much later than in Western culture. Two texts (Περὶ τῆς τῶν ἱεράκων ἀνατροφῆς τε καὶ θεραπείας, *On breeding and caring hawks*, and Ὀρνεοσόφιον ἀγροικότερον (*Other ornithological*

134 *Description of a crane hunt*, ed. Kurtz, l. 69–71.
135 See esp. *Ibidem*, l. 59–60, 180, 307–12.

*treatise on hawks*), as well as a short treatise (Κυνοσόφιον, *On breeding dogs*) derived from Arrian and imparted recommendations about diseases and accidents affecting dogs. The latter can be reasonably attributed to a physician named Demetrios Pepagomenos (see chapter 11 of this volume).[136] Pepagomenos, relying on knowledge neither bookish nor superstitious, but based on experimental practice, describes six hunting techniques with the falcon, and deals with handling, breeding and curing. He makes remarkable helminthological observations when commenting diseases and treatment of the eyes. Other than this last text, all the "technical" writings mentioned above prove literary conventions and traditional information to be more important than practical matters and professional utility. For example, information on farm constructions for animals in *Geoponica* (including henhouses and fishponds) fall far behind the details provided by e.g. Columella in his *On Agriculture*.

## 7 Aristotelian Commentaries and Natural Problems

### 7.1 *Aristotelian Commentaries*

The Aristotelian zoological corpus, which was the richest and most scientific production of antiquity in this field, failed to be the subject of any known Greek commentary in ancient times until the 12th century.[137] This is all the more surprising since "Aristotelian philosophy found in the commentary format not only a means of transmission, but also a preferred tool for the development of doctrine."[138] A compendium entitled *On Aristotle's philosophy* only partly preserved in a 10th-century Arabic epitome dealt with zoological treatises,[139] but it was apparently no more than an abridged paraphrase. The author, named Nicolaus, has been generally identified with Nicolaus of Damascus (1st century), but he might be a later scholar of the 4th century.[140] The founding of the University of Constantinople in the 11th century by Constantin Monomachos did not enhance the commitment of scholars to Aristotelian biology: neither the Platonician Psellus, nor his friend the Aristotelian John Xiphilinus, nor his successor at the head of the University John Italus wrote commentaries on zoological matters. In contrast, much earlier Arabic civilization took a close interest in Aristotelian zoology. This corpus was translated in

136 See also Lazaris, "La production nouvelle en médecine vétérinaire sous les Paléologues."
137 See Gottschalk, "The Earliest Aristotelian Commentators," pp. 67–68.
138 Fazzo, "Aristotelianism as a Commentary Tradition," pp. 3–4.
139 See Kalogeridou, *Ανωνύμου (;) Εἰς τὸ Ἀριστοτέλους Περὶ ζῴων γενέσεως*, p. 247.
140 See Fazzo, "Nicolas le Péripatéticien, dit le Damascène: Notes pour une étude."

the 9th century, included in a large encyclopedia entitled *Book of Animals*, commented by Avicenna (11th century) and newly translated and studied during the 12th century in the Toledan School within the circle of Avempace. The oldest Byzantine manuscripts of zoological treatises (*Parts of Animals* [*PA*], *Generation of Animals* [*GA*], *Progression of Animals* [*IA*], *On Respiration* [*Resp.*] and *History of Animals* [*HA*]) date back to the 9th century, but most of them are from the 14th century onwards and we can assume that these works were accessible only to a narrow readership. This is how Michael of Ephesus, another pupil of Psellos, became in the first half of the 12th century (*c.* 1138) the first known Greek commentator on these texts, along with other philosophical works.[141] This task was assigned to him by the princess Anna Komnene, who according to the historian George Tornikes (*c.* 1115–1157) initiated a series of commentaries on previously neglected Aristotelian works:

> The works which philosophers of our time addressed to her bear witness to her love of learning, works concerning those writings of Aristotle on which commentaries had not been written until her time, but the explanation of which was transmitted orally in every kind of form, without certitude and with little zeal.[142]

Michael of Ephesus lost his eyesight while carrying out his mission of writing a commentary on Aristotle, part of a collective undertaking to which his colleague Eustratios of Nicaea also contributed. He left out of his project the *History of Animals*, which played a seminal role in Arabic zoology but was never mentioned in Byzantine times. Michael appears to be very familiar with Aristotle's works and often relies on arguments or examples appearing in other treatises, or drawn from Theophrastus' ethical and biological writings. His concern is to expound Aristotle and to clarify the style when necessary, in an extended paraphrase, but he neither supplies a critical review nor tackles the biological issues from a fresh angle.[143] Intended for a learned readership rather than for students,[144] his commentaries rapidly spread and a Byzantine monk, Sophonias (13th–14th century), who produced paraphrases of the "short treatises on nature" of Aristotle (*Parva Naturalia* [*PN*]) and of *On the soul* (but not of the major zoological works), copied significant parts of them.

141 He supplied a commentary to *Generation of Animals* that has long been erroneously ascribed to John Philoponus.

142 *Funeral oration of Anna Comnena* (fol. 29v), transl. by R. Browning in "An Unpublished Funeral Oration on Anna Comnena," p. 12.

143 Sorabji, *Aristotle Transformed*, p. 21.

144 See Kalogeridou, *Ανωνύμου (;) Εἰς τὸ Ἀριστοτέλους Περὶ ζῴων γενέσεως*, p. 136.

At about the same time George Pachymeres (1242–1310) wrote, under the name of *Philosophia*, a *schediasma* or pedagogical Vade mecum in 12 books, dealing with (the first three books of) *PA* and with *IA* (book 6), *Resp.* in *PN* (book 8) and *GA* (book 9). Pachymeres, even if he depicts carefully and with evident fascination a giraffe offered by the Baybars sultan to the emperor,[145] was not particularly interested in zoology and incorporated these books as just parts of a comprehensive undertaking and encyclopedic project. Preserved in 35 manuscripts and most especially in two autographs with marginal annotations, the text consists of brief discussions on selected topics or statements and stands rather as partial epitome than a proper commentary. Unlike traditional commentaries within the philosophical tradition, divided into quotations (*lemmata*) and accurately following the progression of the source, this text develops in loosely arranged sections, gathering relevant information or quotations from other parts of the commentary on the general production of Aristotelian material. In addition, it is worth noting that each Aristotelian book is thus more or less 'reduced' to a fifth of its original length. Shortly after this, his epitome, combined with Michael's commentaries, served as the chief source for the zoological part of the *Encyclopedia* of Joseph Rhakendytes (13th–14th), another early Palaiologan general compendium that included rhetoric, mathematics, music and theology. Drawing heavily on the works of his Byzantine predecessors, he copies almost *verbatim* book 6 of Pachymeres' *Philosophia* (on *PA* and *IA*), without providing any original information. His contemporary Theodore Metochites (1270–1332) carried out a similar undertaking, devoting 39 books to the natural philosophy of Aristotle and commenting on the zoological corpus. The traditional title *Paraphraseis* given to these essays is misleading, and the work is rather a kind of introductory overview (εἰσαγωγή) or summary. The zoological part of its encyclopedia, which remains unedited, but preserved in half a dozen manuscripts, relies to a great extent on Michael's commentaries.

## 7.2 *Peripatetic Natural Problems*

Apart from the main Aristotelian treatises, Peripatetic concern with animals expressed itself in the ancient collections of Natural Problems. The tradition of mixed physical questions (also known as *Questions and Answers* or *Erotapocriseis* literature), was persistent and widespread in the Byzantine era. It derived from the first Peripatetic *Problemata* (4th–3rd century BCE) and addressed zoological issues.[146] Following the manner of their philosophical

145 *Histories* 3.4, ed. Bekker, p. 239 l. 7–28.

146 See Blair, "The Problemata as a Natural Philosophical Genre."

model, scholars who adopted this method dealt with specific phenomena, phenomena that are regular but apparently contrary to expectations derived from theory or experience.[147] They suggest rather than develop basic principles to interpret and explain the origin and peculiarity of such phenomena. This approach had also been extensively employed since Philo of Alexandria in the theological exegetic literature (e. g. Pseudo-Justin, Augustine) and the Neoplatonic School (e. g. Damascius). However, Byzantine collections or treatises do not have any specific agenda or consistency nor do they raise new questions—just like most of the parallel productions in Western literature. They generally select and perpetuate, without any original insight, issues already largely discussed in Hellenistic and Roman times by authors like Plutarch (*Quaestiones convivales*, *Aetia Romana et Graeca*), Seneca (*Quaestiones naturales*), Athenaeus (*Deipnosophistae*), Gellius (*Noctes Atticae*), etc. The ninth question of the *Solutiones ad Chosroem* of Priscianus Lydus (6th century), only preserved in Latin, tackles the issue of reptile envenoming and attempts to answer the question "whether they inject a venom and a kind of sanies through their bite, or emit a breath or any special power."[148] The entire discussion is very probably only a reformulation of one of Theophrastus's chapters or books referred to by ancient authors such as Diogenes Laertius (*Vitae philosophorum* 5.43).[149] Later texts provide no more innovative contributions. Theophylact Simocatta (7th century), in the 16 zoological questions of his *Questiones physicae* (chap. 1–6, 8–16, 19–20) where he simply replaces the traditional incipit διὰ τί ("why?") by ποιῷ λόγῳ ("for which reason"), claims to answer hackneyed questions as the superfetation of the hare, the drinking abstinence of the crow in summer, the contagion of the electric power of the torpedo ray, or the destructive power of eagle feathers on other bird feathers. This popular text takes the form of dialogue, and was abundantly copied up to the 18th century (about forty known manuscripts) and plundered by later scholars. The ancient philosopher Antisthenes explains natural difficulties (ἔργα φύσεως) to one Polycrates in a dogmatic and somehow ridiculous way, in a text saturated with mythological references: for example, instructed by the example of Narcissus (chap. 3) he reports that elephants are said to agitate the water before drinking, because they are afraid of their reflection. He takes obvious delight in expounding and magnifying the general view supported by folk beliefs (such as the popular account of the impregnation of vultures by the

147 See Theophylact Simocatta, *Physical Problems*, ed. Massa Positano, c. 23 (ξένον τῶν τῆς φύσεως νόμων).

148 *Answers to Chosroes*, ed. Bywater, pp. 94.3–98.16.

149 See Zucker, "Théophraste à mots découverts."

wind, thus compensating for the absence of the male in the species). Despite the rich (and unfinished) list of 18 sources given by Simocatta in chap. 38, including Democritus, Theophrastus, Aelian, and Alexander, the direct use of these authors is not sustained by the text. Michael Psellos, who also practices the genre in a selection of astronomical questions (*De omnifaria doctrina*) and recast and reformatted Aristotelian meteorological knowledge in the same form, offers a more conventional inventory of several zoological peculiarities in an opusculum.[150] In the section devoted to animals,[151] he discusses typically discrete natural mysteries, such as the odourlessness of cow dung, the fact that Libyan animals only drink during winter, or that wild animals are unicolored. But the text is entirely drawn from a very influential collection of the 3rd century previously ascribed to the philosopher Alexander of Aphrodisias.[152] This kind of collection where the zoological data are divided into many short units, easy to extract and reuse, also influenced historians such as Michael Glykas, who inserts almost *verbatim* into his commentary on the Creation full excerpts from Alexander as well as from Simocatta.

## 8 Animal Costume

Popular texts involving animals are too often overlooked by scholars when reviewing medieval knowledge.[153] Byzantine authors act in the same way, as witnessed by the case of the *Physiologus*, and refrain from mentioning them in their scientific or literary works. Yet some animal tales are very instructive. They sometimes provide accurate details which reflect concrete interest and cultural concerns for animals. Admittedly, this is not the case in the tradition of the fable, be it the Aesopian or the Indian one, where animals are chiefly zoomorphic masks in stereotyped or human situations, such as the text entitled *Stephanites and Ichnelates*, a Greek adaptation by Symeon Seth (11th century) of the Arabic collection *Kalila and Dimna* drawn from the *Panchatantra*. We are unable to find more topical information in the poetic divertissement or rhetorical pieces of Theodore Prodromos (12th century): The *Κατομυομαχία* (*Battle of Cat and Mice*) is a heroic parody, in the mode of the *Βατραχομυομαχία* (*Battle of Frogs and Mice*) and full of dramatic references; the two brief and

150 *Opuscula logica, physica, allegorica, alia*, ed. Duffy, n° 55, pp. 241–83 (listed among "incerta et spuria").
151 Opus 55, l. 1–603.
152 Pseudo-Aristoteles (Pseudo-Alexander), *Supplementa Problematorum*, ed. Kapetanaki/Sharples, book 1.
153 See Beck, *Geschichte der byzantinischen Volksliteratur*, pp. 173–79.

complementary parts of *Τὰ σχέδη τοῦ μυός* (*A Pious Mouse and a Deadly Cat*) are school exercises and satirical works where cat and mouse are no more than disguises.

However, two poems of the late Palaiologan period deserve special consideration and display interesting information on both the physical description and technical use of animal products. The *Πουλολόγος* (*Book of birds*, *c.* 1380, of 668 unrhymed political verses), contemporary with Chaucer's *Parlement of Foules* and John Lydgate's *Debate of the Horse, Goose, and Sheep*, appears as a succession of individual "battles" between 14 pairs of birds (including the bat), gathered by the eagle at the wedding of its son. In this feigned judicial tournament, accusations (*κατηγορία*) and apologies (*ἀπολογία*) are centered on anatomical and ethological characteristics and common reputations amongst men. Even though the text was essentially a political one, offered as a parody on the war between John Cantakouzenos and Alexios Apokaukos in the mid-14th century, the descriptions, filled with metaphors and exaggerations, provide details about animal consumption and the daily use of animal products.[154] The swan, which is the leadoff speaker, begins by boasting that he is a king's dish (v. 26 and 51). He compares the flesh of the pelican to the jelly-fish (v. 46), and mentions the use of its skin by tanners (v. 53–56). Among the flood of insults in which the birds trade, some instructive data stands out. There is the children's game of dragging a heron around by a rope (v. 97–98), or the rich women's habit of consuming peacock eggs to achieve fresh breath (159–161).

The *Διήγησις τῶν τετραπόδων ζῴων* (*Tale of the Four-footed Beasts*, *c.* 1463, an anonymous satirical poem of 1082 v.), addressed to youngsters and students as an instructive gallery of 20 animals (v. 1–6) takes the form of a similar series of rhetoric *agones* between pairs of animals who disparage their opponent and praise themselves in return.[155] The meeting convened by King Lion takes place under a truce where he compares the qualities and defects of *useful* quadrupeds and which ends in a general fight between carnivorous and herbivorous creatures. This turns in favour of the latter. Animals do not pride themselves on their pedigree (as is usually the case in the *Poulologos*), nor on their natural capacities, but on their utility for humans. The text, focussed on the economic benefits provided by animals, displays a range of precious information about the daily use of animal products as food and technical resources: hare's legs used by goldsmiths (v. 310–3), deer leather to make tinder cases (v. 343–5), pig's bristles to sprinkle the congregation in the Church or to produce

154 See Tsavari (ed.), *Ὁ Πουλολόγος*, pp. 247–305.

155 See Tsioumi (ed.), *Παιδιόφραστος διήγησις τῶν ζῴων τῶν τετραπόδων*; Nicholas/Baloglou, *An Entertaining Tale of Quadrupeds*.

threads and pencils for cobblers and painters (v. 384–91), boar's teeth used to polish bookbinding (v. 402–4), or elephant's ivory for bed and mirror frames, crosses, game pieces, knife handles, combs etc. (v. 914–28). As in the *Poulologos*, some popular stories adopted by the *Physiologus* are mentioned, such as the physiological elephant (v. 942–57). Two poems of the 14th–15th centuries must be briefly mentioned though they do not provide any zoological interest, beyond their animal names. The animal epic *Ὀψαρόλογος* (*Book on fish*)[156] consists of 86 unrhymed and irregular verses featuring a parodic and summary trial at the end of which Mackerel (Τσῆρος), denounced for conspiracy, is condemned to have its beard shorn by the emperor Whale (Κῆτος). The *Συναξάριον τοῦ τιμημένου γαδάρου* (*"Legend" of the Honorable Donkey*), which survives in two versions of respectively 393 and 540 political verses, is a fable of how a humble donkey outwits a fox and a wolf who intended to devour him.[157]

## 9 Conclusion

With regard to zoology, it is impossible to endorse the epistemological premise of Stephanides who mentions a "naturalistic unbroken tradition from early Antiquity until today" (1932, p. 12). Compared with Arabic literature, the paucity of Byzantine literary production and innovation in describing, observing and questioning animals is patently clear. If we adopt the standards and expectations of historians of biology we have to face this very disappointing statement: in the Byzantine era animals were no longer a philosophical, nor even an intellectual concern. Many zoological issues, like structural organization, reproduction processes, metamorphosis of insects, breathing of fish, intraspecific communication, spontaneous generation, metachromatism of animals, discussed in Peripatetic traditions are at best only alluded to and described as mere facts and never problematized. It is a frustrating verdict, although we have to remember that after the blossoming of the Aristotelian school (including his immediate successors like Theophrastus, Clearchus, Eudemus, and Straton) there was from the Alexandrine period onwards no significant concern with theorizing animals except for ethological-moral issues, which led in turn to plain anecdotes in the way of Aelian narratives and gave the impression

156 For the text, see Winterwerb, *Porikologos*, pp. 252–53; see Beck, *Geschichte der byzantinischen Volksliteratur*, pp. 178–79.

157 For the text, see Alexiu, *Η Φυλλάδα του γαδάρου*; see Beck, *Geschichte der byzantinischen Volksliteratur*, pp. 178–79.

that everything had been concluded once and for all by Aristotle without the need for any supplement or further reconsideration.

Yet Byzantine authors only accentuate a general evolution in Greek zoological knowledge rather than distort a classical legacy. Aristotle offered a two-dimensional vision of animals, that are considered simultaneously as particular cases and common structures. In Alexandrine times this conception already begun to disappear, and the remaining zoological production of this period consists mainly in depictions of particularized animal characteristics, which form a conceptual menagerie or collection of contrasting figures, that practically destroyed the idea of a biological unity. Roman zoology from the Republican period onwards followed this path and can be essentially regarded as a moral-laden and, so to speak, alternative *ethnological* discourse, consisting in individual physical and ethological portraits. The fragmentation of zoological knowledge already perceptible in the Alexandrian compilations or in Plutarch prevailed in Constantinople. This model was expressed in three ways: that of the monographic record centered on a few attributes, typical of the *Physiologus*; that of the short animal story as displayed in the poetic pieces of John Tzetzes or Philes' adaptation of Aelian; and that of the "question" as in the tradition of the Pseudo-Alexander *Problems*. The first type is obviously the most popular, carried out sometimes in a caricatured form, as in the *Commentary to the Hexaemeron* of the Pseudo-Eustathius. It offers a series of vignettes disconnected from the frame of the commentary, especially since animals are not introduced on the day of their creation.

Byzantine authors were no more concerned than their predecessors to carry out experiments on animals or systematically study their natural properties and ways of living. Even in philosophical commentaries and the "Natural problems" tradition there is no trace of any theoretical thinking or biological questioning. The *historia* of animals in Aristotle's view was a dynamic "inquiry" into biological processes and animal structures and behaviour intended to identify and emphasize the consistency of natural beings and the rationality at work in them down to the smallest details. His *Historia Animalium* became no more than a huge petrified depository of official information on animals, giving rise to occasional additions, and above all to multifarious literary variations, and numerous narratives. All Byzantine texts, probably including the work of the sophist Timotheus, recycle and rephrase previous literature, based primarily on Aristotle's writings. The Greek literature of this period, but Latin literature as well, is full of inconspicuous data and anecdotes scattered throughout the general literature (historical, theological, geographical books, etc.) and in medical works. Christians adopt the wonders Pagans collected and "explain" them as direct proofs and products of God's providence. All in all, the only *new*

documentation on animals consists in raw depictions of exotic species in geographical books and the practical observation of horses, dogs and birds used for hunting and serving in war.

As has already been mentioned, explaining this lack of interest by the absence of institutional or political support or by the pressure of Christian doctrine misses the point. No obvious evolution in zoological concern can be detected during the period, except that most zoological writings (apart from Michael's and Philes' works) were produced in late antiquity before Justinian. The "Palaiologan Renaissance" with its "Revival of the sciences" did not break the mold. Besides, if natural sciences had been totally despised by churchmen, we would not see disciplines like astronomy or alchemy attracting special attention and evolving significantly in that same period. One could say that animals had theoretically significant qualities to prompt greater curiosity and concern: even if animal products were less used for medical purposes than plants, due to the higher complexity of their anatomy and the conspicuous variety of their behaviour they are basically richer objects than plants. Remarkable scholars like Nicephorus Blemmydes (12th century) or Nicephorus Gregoras (13th century) are still more interested in alchemy or astronomy than in life sciences (see chapters 6 and 13 of this volume). A doctor and Arabic-speaking scientist like Simeon Seth, translator of a collection of animal fables, never considers the case of animals in his *Conspectus rerum naturalium* (*Treatise on the natural sciences*).

The traditional idea promoted by naturalists, historians of science and philologists, about a drastic decline of interest within Byzantine zoology will continue *as long as we persist* in adopting the same conceptual framework and the same modern cultural prejudices that led to this judgment. However, if the animal-related documentation that has come down to us provides only a small quantity of evidence, compared to modern criteria and modern scientific expectations, we should be careful not to draw anachronistic conclusions. Indeed, a radical shift in our perspective is needed to assess correctly Byzantine zoological discourse, and a full awareness of the actual bias of the underlying current judgements. This bias consists of four values of our time that can be summarized in the key-words: Aristotle, Innovation, Transcription and Experience.

We are probably unconsciously driven by an ancient and possible not undeserved devotion to Aristotelian achievements together with his *unrepresentative* way of thinking and teaching, so that we feel dissatisfied with the divergent intellectual choices made by later generations. Admittedly, as K. Vogel puts it, "Byzantine scholars for the most part ignored the deeper questions of zoology such as were treated by Aristotle (the development of organisms, the

physiology of organs and their purpose)."[158] The Byzantines were obviously not Aristotelian in this respect—but then neither were the Romans, nor the large majority of ancient Greeks. It should also be noted, by the way, that a similar judgment applies to Renaissance zoologists. Progress in this direction was largely made possible by the development of new technical means of observation. The main problem is here that we define zoology restrictively. We see it from the point of view of the way in which our modern culture has promoted scientific methods and aims. Since Alexandrine times Greek civilization simply pursued other cultural options and developed other kinds of discourse, far removed from our Aristotelian model … and obsessions.

It might seem self-evident that all cultures have the ambition to enhance and expand inherited information. But within the Byzantine value system these two modern intellectual qualities were largely irrelevant. We should ask ourselves, therefore, if these two factors of technical progress are not in fact overrated. Furthermore, in a pre-Gutenberg world patrimonial commitment had to face heavier constraints. Managing a literary legacy has been a prominent issue for a long time and a compulsory function among learned people. In addition, scholars have always been more inclined to compete with contemporaries on topical debates than carry forward the torch of disciplines, especially when these "disciplines" (as in the case of what we now call zoology or biological science) did not belong to the pedagogical tradition. It is therefore inappropriate to regard a culture that did not commit itself to producing an original and analytical literature which fails to correspond to any modern field of knowledge as uninterested in animals or even in zoological knowledge. This period was not in an intellectual or even a scientific coma: it was able to copy, preserve and carry a great number of ancient works (including Aristotle's production in particular) until the technical conditions of the diffusion and preservation of the written text made its survival simpler and safer.

Another reason for the modern denigration and misconception of Byzantine culture is the illusion that *written knowledge* and knowledge coincide. When the text is almost all that remains of a society we are too easily deceived into following this misleading shortcut. What Byzantine scholars did write about animals can be substantiated: what Byzantine people actually knew is far more difficult to determine. Literary data expresses what professionals decided to formalize and to entrust to written communication. The technical developments in seafaring, the clothing industry or wood manufacturing, all tell us that practical knowledge is seldom, if ever, transmitted through literary

158 Vogel, *Byzantine science*, p. 284.

production. It seems clear that a literary collection such as *Geoponica*, says very little about the oral traditions, knowledge and skills of farmers.

Finally, we should consider that animal concern or knowledge cannot be only defined by, or limited to, listing and commenting on natural data acquired by observation or through intentional and invasive experiments. The ultimate purpose of zoology, as of every natural science, is the interpretation of the phenomena. Byzantine scholars did not practice systematic and *extensive investigation* of natural beings, but they did practice *intensive interpretation* of cultural information on animals. The texts discussed above are eventually only a part, maybe the most concentrated and obvious part, of the documentation of animal interest. We attribute value to Aristotle's writings because of the quality of his physiological and anatomical descriptions, and of the amount of concrete and diverse information he provides. In the Byzantine worldview, this approach was not the most efficient way to intellectually take advantage of, or access, animal reality. To put it in very general terms, Byzantine people, who belonged to a culture that greatly differs from our own, saw different things when they looked at the world. In a manner most probably less theology-laden than is generally thought, they linked the natural world to the psychological realm and to moral reality. They were less concerned with biological questions than with meaningful answers, and were convinced that interpreting texts was an alternative way of deciphering nature. In this process, which focuses on moral and physical interpretation, it is believed that Christian authors retained only stereotyped animal images in exegetical commentaries and doctrinal writings, and that they restricted animals to moral or spiritual clichés. This is far from the case. Any person familiar with animal symbolism in these texts knows that the diversity of interpretation and inventiveness displayed in moral and exegetic writings about the behaviour or the characteristics of one single animal is striking. Leaving aside pedagogical handbooks that offer scant and unsurprising symbolism and trivial definitions, "Christian" authors appear inventive at developing, in different ways, the potential meanings of animal figures through *exempla*. Remarkably, the *Physiologus* tradition, which bears witness to an increased anthropocentric vision of animals (whether it was regarded as means either of valuing or using animals for moral purposes), while encapsulating the nature of animals in only one or two key modes of behaviour, gives rise to multiple, diverse and often contradictory exegetical options. This intellectual approach, which should not be allowed to overshadow the daily and concrete experience that people had with animals, is unquestionably also, in its own way, a zoology.

CHAPTER 9

# Botany

*Alain Touwaide*

## 1 Introduction

The project of an essay on botany in Byzantium raises the question of the very existence of botany as a scientific discipline in the Byzantine World. There were practical activities that were botanical in nature (e.g. agriculture) many of which demanded a knowledge of plants, their reproduction and life cycle, and the possible selection and improvement of species for human and animal consumption, in addition to the massive production of ornamental species for decorative purposes. Current historiography in the history of botany, however, does not usually take Byzantium into account or, if it does, it reduces it to a 'dark age' marked by a low or even negligible interest in the natural world.[1]

Over the past century some research has been conducted, especially among historians of art who have made detailed studies of the splendidly illustrated manuscripts of *De materia medica*, by the Greek Dioscorides (1st cent. CE).[2] In several such codices the text is accompanied by coloured representations of plants that are sometimes naturalistic. One of these manuscripts is the so-called *Dioscorides of Vienna* (Vienna, Österreichische Nationalbibliothek, medicus graecus 1) dated to *c.* 512 CE, which also contains other texts and constitutes an illustrated collection on natural sciences. During the 20th century it has been extensively analyzed and repeatedly reproduced. The dedication illustration representing the princess Anicia Juliana (462–527 CE) has been taken as a sign of a new artistic style developed in Constantinople in the

1 For a thorough analysis of the historiography of medieval botany (including Byzantium, the West, and the Arabic World), with a special emphasis on the primary sources, the methods, and the results (updated up to 2010), see Touwaide, "Botany." Also, though more general, Touwaide, "Byzantine Science." Complementarily, on the methods in the history of medieval science, see Powrie, "Historiography of Medieval Science."

2 The Greek title of the work as it is attested by most of the manuscript tradition reads περὶ ὕλης ἰατρικῆς, correctly translated into Latin ad *De materia medica*. A scientifically correct translation into English would be *On the natural products used for the preparation of medicine*. Because of its length, the treatise will be conventionally identified here by its traditional Latin title *De materia medica*.

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6th century characterized by plasticity, possibly on the basis of renewed observation.[3]

The limited knowledge of botany in Byzantium that this first glance at the current state of research suggests, might be accounted for by the apparent paucity of primary sources. No work specifically devoted to plant science seems to have been available in Byzantium apart from two classical texts: *Historia plantarum* (*Inquiry into Plants*) by Theophrastus of Eresos (372/371 or 371/370–288/287 or 287/286 BCE), regarded as the founding work of botany, and Dioscorides, *De materia medica*, cited above and credited with a similar founding status in the field of pharmacotherapeutics.[4] *De plantis* (*On plants*) by Aristotle (384–322 BCE) was soon lost in Greek. It was recovered only late in Byzantium, apparently within limited circles, in a retro-translation into Greek of its Latin version (itself resulting from translation from Arabic of an edition of the original work). Similarly, Theophrastus' treatise does not seem to have circulated widely in Byzantium,[5] contrary to Dioscorides, *De materia medica*, which was not, however, a treatise on botany *in se* and *per se*.

The impression of an absence of botanical knowledge in the Byzantine world that this initial survey of available sources and literature suggests, will probably be confirmed by a comparison between Byzantium and the Arabic world, as the latter has often been recognized in historiography for the development of an original, complex, and articulated body of knowledge about plants. The history of the Aristotelian *De plantis*, seems to provide confirmation of this. It was translated from Greek into Syriac and, later, from Syriac into Arabic, but it disappeared in the early Byzantine period and does not seem to have been the object of any search until the 14th century.

3 In this sense, see Wright, *Codicological notes on the Vergilius Romanus*, pp. 10–12. Although the author does not exactly reference it, the miniature referred to appears on fol. 6v. Additionally, he does not specify whether this "new style" applies to other representations, be they of humans or plants.

4 The scientific field covered by *De materia medica* is traditionally identified as *pharmacology* in contemporary philologico-historical literature. Though possibly correct from an etymological viewpoint (the study of medicines) and historically attested in Latin in the medico-scientific literature of the Renaissance and the following centuries, this meaning of the term became obsolete in the 19th century and is thus currently anachronistic as *pharmacology* now refers to a much narrower, technical field (drug discovery). To avoid confusion it is preferable to use the term *pharmacotherapeutics*, which exactly corresponds to the ancient activity, including theoretical reflections and scientific systems built to explain the action of medicines.

5 The work is attested by a limited number of manuscripts. See (in chronological order) Wilson, "The manuscripts of Theophrastus," and Einarson, "The manuscripts of Theophrastus' *Historia Plantarum*."

The reduced number of relevant primary sources referred to in the Western historiographical tradition has led to the conclusion that botany was not a science in Byzantium. It has also led to a lack of interest in the topic. This in its turn has taken the form of circular reasoning which justified a neglect of specific research into Byzantine botany and, consequently, has discouraged scholars from revisiting the well-established narrative.

Recent developments, however, are breaking the direct, causal relationship – and its negative circular effect – between the supposed absence of sources and the consequent pointlessness of undertaking fresh research, a position that, implicitly if not explicitly, has been established by historiography. A systematic screening of extant Greek manuscripts – all Byzantine – giving special attention to botany in its multiple forms has led to the identification of a range of texts, all very different in nature, which attest to an activity around plants suggesting, at the very least, some knowledge of botany. Similarly – and complementarily – archaeobotany is bringing to light macro-remains of plants, and traces of plants in the soil of sites that are currently being excavated. Furthermore, laboratory analysis of material recovered from previously or newly explored sites makes it possible to identify traces of plants in artefacts of all kinds hinting at practices doubtlessly resulting from a refined and precise knowledge of the plant world in Byzantium that can qualify as truly *scientific*.

This chapter aims to lay down the basis for possible new investigations into the history of botany in Byzantium. To dispel the negative image of Byzantine botany found in currently available literature and to debunk the many misconceptions it has generated, it starts with a summary presentation of the textual body mostly referred to in previous literature. It then pursues new approaches to the available material, in an attempt to identify characteristically botanical components in Byzantine activity, particularly *scholarly botany*, which might be compared to contemporary botany comprising speculative and analytical botany. A shorter survey of *daily-life botany* then follows, which is rather similar to what is now called *traditional practice*. Such data assembled from the sources are preceded by an overview of the natural environment of Byzantium – together with the way such environment was perceived – with all the elements that such perception involves (or not).

## 2 The Textual Body

The botanical corpus usually studied in the Western historiography of Byzantine botany was made of the following works that Byzantium received from classical antiquity (they are cited here in the chronological order of their

author): *De plantis* attributed to Aristotle; Theophrastus, *Historia plantarum* and *De causis plantarum*; and Dioscorides, *De materia medica*. In addition we could add the following texts that have rarely or never thus far been taken into consideration in botanical historiography (in chronological order of authors or origin): *Corpus Hippocraticum*, *De victu*; Galen, *De simplicium medicamentorum temperamentis et facultatibus*; the agriculturists mostly equated with the *Geoponika*; and a vast set of works of different types resulting from the translation into Greek of material originally in Arabic or Persian that until recently has rarely (if at all) been explored. All these works or groups of works are briefly described here (in the chronological order of their writing).

### 2.1 *Hippocratic Corpus,* De Victu

The treatise *De victu* (*Regimen*) attributed to Hippocrates (460–between 375 and 351 BCE), but most probably not by him, comprises three books,[6] the second of which is mostly a catalogue of plants consumed as foodstuffs by humans, together with their health benefits.[7] This catalogue is structured in terms of major categories of plants from cereals to vegetables, and each botanical species is discussed within these categories.

### 2.2 *De Plantis*

A treatise *De plantis* (*On plants*) attributed to Aristotle circulated in the late Byzantine world.[8] It is not the exact text of an authentically Aristotelian work, but the translation into Greek of a text on botany that went through several versions across the Mediterranean world, and seems to ultimately go to back to a compendium of Aristotle's philosophy by a certain Nicholas traditionally, but not necessarily rightly, identified as Nicholas of Damascus (*c*. 64 BCE–? CE).

*De plantis* contains a set of notes of uncertain origin, as we do not have any clear indication that the Stagyrite did compile such a work.[9] It might have been a set of un-coordinated material in the way of the *Problemata* coming

6 From Littré's edition on (*Oeuvres complètes d'Hippocrate*, vol. 6, pp. 466–663), these three books are followed by a fourth, which is, in effect, another work, on dreams, that has been incorrectly assimilated to *De victu*.

7 For editions of the Greek text with facing French translation, see: Joly (ed.), *Hippocrate, Du régime*; and Joly/Byl (eds.), *Hippocrate, Du régime*. For an edition with facing English translation, see Jones (ed.), *Hippocrates*, Volume IV, pp. 224–447.

8 On this treatise, see Moraux, *Der Aristotelismus bei den Griechen*, pp. 487–514. For the Greek text, see Hett (ed.), *Aristotle in Twenty-three Volumes*, vol. 14, pp. 142–233 (with facing English translation), and, more recently, Drossart Lulofs/Poortman (eds.), *Nicolaus Damascenus "De plantis,"* pp. 589–624. For a French translation, see Federspiel, *Pseudo-Aristote, Des plantes*.

9 For an inventory and analysis of references to plants and comparisons between plants and animals in Aristotle's biological works, see Thanos, "Aristotle and Theophrastus on plant-animal interactions."

from the Aristotelian school. Whoever the author was, it is a theoretical analysis of fundamental botanical concepts, with descriptive data (growth of plants, types and parts, habitat, process of leaf shedding, colour, fruits and saps) and analytical considerations (plant reproduction, including genus and species, together with speciation), all of which are indispensable for taxonomical purposes. Going further, the treatise speculates on the status of plants as living creatures (ensoulment). All such elements are complemented by data on practical techniques (grafting and improvement of species). Concepts and theories on several such points drawn from the works of earlier scientists are collected, summarized, and analyzed according to the typical scientific method of the Lycaeum (ἱστορία).

### 2.3 *Theophrastus,* De causis Plantarum *and* Historia Plantarum

Aristotle's student and successor as the head of the Lycaeum in Athens, Theophrastus, compiled two major botanical syntheses that earned him the title of *Father of Botany* in Western scholarly literature. *Historia plantarum* (*Inquiry into plants*) is a systematic analysis of the plant world, with its general quadripartite division and a definition/description of all plant parts, which is considered to have laid down the basis of the Greek botany and botanical lexicon.[10] Its ninth book, considered for a long time inauthentic but now recognized as Theophrastean, was originally an appendix devoted to the therapeutic uses of plants. At some point in time, it was followed by another small treatise on the sap of plants. Both have been integrated into the text of *Historia plantarum* during their manuscript transmission and they have been identified as the book IX of the *Historia Plantarum*.[11] *De causis plantarum* (*On the causes of plants*) is a specialized study of plant genesis.[12]

### 2.4 *Dioscorides,* De Materia Medica

Dioscorides, the author of the work traditionally identified as *De materia medica*,[13] was most probably born in Anazarba (now Anavarza, in Turkey), in

10 Greek text with facing English translation in Hort (ed.), *Theophrastus, Enquiry into plants*, 2 volumes, to be completed with Gemmill, "The missing passages in Hort's translation of Theophrastus" for the passages censured in, and eliminated from, Hort's edition. More recently, see, with facing French translation, Amigues (ed.), *Théophraste, Recherches sur les plantes*, 5 volumes, with the full text.

11 See in Amigues' edition, vol. 5, pp. vii–xiii (about their authenticity) and xli–lvii (about their assimilation into Theophrastus' textual corpus).

12 Greek text with facing English translation in Einarson/Link (eds.), *Theophrastus*, and in Amigues (ed.), with facing French translation.

13 The standard edition of the Greek text (which is in need of revision) is by Wellmann (ed.), *Pedanii Dioscuridis Anazarbei, De materia medica libri quinque*, 3 volumes.

Cilicia, sometime during the 1st century CE. In the preface to his work, he explicitly states that he had been interested in botany from his early years and that he travelled extensively in order to gain a personal knowledge of plants. The historiographical tradition according to which he was a military physician accompanying the Roman troops in the East during the reign of emperors Claudius 41–54 CE) or Nero (54–68 CE), is not substantiated by any evidence.

As its title in the standard edition suggests (περὶ ὕλης ἰατρικῆς), the work is about the matter (ὕλη) of medicine (ἰατρική), that is, the natural products used as ingredients for the preparation of medicines.[14] These products were of plant, animal and mineral origin, with the plants amounting to circa 70% of the total number of materia medica (actually over 700 of the *c.* 1,000 substances studied in the treatise).[15] Each substance is dealt with in a chapter made up of three major parts: description, therapeutic properties, and medicinal applications. When the description of the plants is present (which is far from being always the case),[16] it distinguishes their several parts for correct identification. Complementing the written text, colour representations of the plants are present in over 30 Greek manuscripts.

### 2.5 *Galen,* De Simplicium Medicamentorum Temperamentis et Facultatibus

A scientist with wide-ranging interests and a prolific writer born in Pergamum, Galen (129–after [?] 216) compiled a major collection of data on plants in his work currently identified as *De simplicium medicamentorum temperamentis et facultatibus* (*On the mixtures and properties of simple medicines*).[17] The original title was probably shorter, referring only to the *properties* (δύναμεις) of simple medicines.[18]

Considered to have contained 11 books, in fact the work is made of two parts as its manuscript tradition indicates: the first part (Books I–V) contains Galen's theory on how the properties of simple medicines can be determined. The

14 It seems that the original title (if any) was περὶ ὕλης only (see Touwaide, "La thérapeutique médicamenteuse," pp. 258–61).

15 Several chapters deal with more than one substance, for example the different species of the same genus according to ancient taxonomy.

16 For many plants Dioscorides mentioned only that they are well known (γνώριμον).

17 The only available edition of the Greek text (which is in urgent need of revision) is by Kühn (ed.), *Claudii Galeni Opera omnia*, vol. 11, p. 379–vol. 12, p. 377.

18 Jacques, "La méthode de Galien pharmacologue," p. 123, note 70, lists the different forms of the title according to how Galen himself referenced the treatise in his two works on compounds medicines. More recently, Petit, "Théorie et pratique," p. 81, note 1, refers only to the manuscripts of the text.

second part (Books VI–XI) is a catalogue of materia medica divided by their nature: vegetal (Books VI–VIII),[19] mineral (Book IX), and animal (Books X–XI). In the latter part, Galen mostly translates the therapeutic properties of plants according to his own synthesis of the quaternary system of qualities of Hippocratic origin (hot, cold, dry, and wet) and his theory of four degrees of intensity of such qualities, without providing much in terms of plant description.[20]

### 2.6 *The Agriculturists*

Agricultural techniques provided material for several works and treatises in antiquity, from Hesiodus (8th cent. BCE), *Opera et dies* (*Works and days*), and Xenophon (*c.* 430–*c.* 354 BCE), *Oeconomicus*, in the Greek world, to Palladius (late 4th/early 5th cent.), *Opus agriculturae* (*On agriculture*), in the Latin world. While the Latin production has been preserved, most of its Greek counterpart is now lost, and is known only through lists of authors' names in Latin treatises on the topic together with fragments in the body of agricultural literature that circulated in Byzantium in several forms, the most recent of which is the *Geoponika*.[21] Although the *Geoponika* refer to over thirty authors, very few of the extracts that make up its text actually derive from the authors to whom the extracts are attributed.[22]

Whatever their sources, the *Geoponika* represent a unique collection of material on plants together with knowledge directed to their uses in Byzantium.[23] The twenty books that make up the collection cover a broad range of topics related to farming, agriculture, nutrition, and therapeutics, from astronomy, the calendar and the weather (Book I and also III, with the activities month by month) to fowl, domestic animals, cattle and fish farming (Books XIV–XX), together with the following topics related to plants: seeding, manuring, weeding and harvesting (Book II), wheat, bread and pulses (Book II.27–41), vine (Books IV–V) and wine making and drinking (Books VI and VII, respectively), olive tree and oil (Book IX), fruit and other trees (Books X and XI.1–14, respectively), ornamental and alimentary plants, together with the therapeutic applications of the latter (Books XI.15–30 and XII, respectively), and plant pests (Book XIII).

19 Edition as above note 17, vol. 11, p. 789–vol. 12, p. 158.

20 The recently published volume *Brill's Companion to the Reception of Galen* edited by P. Bouras-Vallianatos and B. Zipser does not provide substantial new information on the history of this treatise in Byzantium.

21 See also chapters 8 and 11 of this volume.

22 For a study, see Guichard, "Sources et constitution des *Géoponiques*," with the list of referred authors on pp. 273–74.

23 For the Greek text, see Beck (ed.), *Geoponica*. English translation by Dalby, *Geoponika. Farm Work*. Modern translations into French, Italian and Spanish are available.

### 2.7 *Translations from Arabic and Persian into Greek*

A significant number of manuscripts (almost 200) transmit a no less significant number of texts (over 70) that are explicitly presented – or can be identified by their contents – as translations from Arabic or Persian into Greek. If authorship and attributions are to be trusted, they date from the late 10th century to the mid-14th century, with most of them dating to the late 13th and early 14th centuries.[24] Though covering a broad range of topics (from diagnosis to remedial treatment), these texts of different length (ranging from one or a couple of formulae for medicines to vast comprehensive manuals) and types (from lexica to prescriptions for remedies), all have in common the fact that they refer to multiple plants either previously unknown to the Byzantines or possibly known to them and identified in the texts through their Arabic or Persian names. The best known among these works characterized by an Arabo-Persian influence is the treatise *De alimentorum facultatibus* (*On the properties of foodstuffs*) by Symeon Seth, which includes material from Arabic medicinal literature.[25] Another is the translation of Razi's treatise *De pestilentia* (*On smallpox*), recently attributed to the same Seth.[26]

## 3 New Approaches to Botany in Byzantium

### 3.1 *Sources and Methods*

Available studies in the history of botany in Byzantium have traditionally been based on textual material, mostly, if not exclusively, Dioscorides' treatise. Particular attention has been paid to the inventory and tradition of its manuscripts and history-of-art studies of the plant representations. Until now, the focus on this work and the approach to it, however justified they might seem, implicitly relied on a concept of botany as floristic in nature (that is, the study of plants and plant groups by geographical areas), to which was added in recent times an interest in phytophysiology and therapeutics (now called 'phytotherapy').

A renewed inventory of Greek medico-scientific manuscripts made on the basis of a more comprehensive definition of botany as both the science and the activity related to plants, has yielded new codices and texts (both authored

24 For a survey of this corpus, see Touwaide, "Arabic Medicine in Greek Translation. A Preliminary Report."

25 For the Greek text, see Langkavel (ed.), *Simeonis Sethi Syntagma de alimentorum facultatibus*.

26 For the Greek text see Kouzis (ed.), *Ῥάζης λόγος περὶ λοιμικῆς*. For the attribution, see Congourdeau, "Le traducteur grec du traité de Rhazès sur la variole."

and anonymous) that had not previously been taken into consideration. Using Diels' catalogues of Greek medical manuscripts as a basis,[27] the search was expanded by consulting general[28] or specific printed catalogues of manuscripts,[29] in addition to the systematic browsing of collections.[30]

This increase in the textual body had two effects. First, it permitted the inclusion of scholars and scientists who, though they had been previously known, had not been considered as interested in the topic. Second it served to identify previously unknown *botanists*. Similarly, a systematic screening of recently published medical prosopographies of classical and late antiquity made it possible to identify several physicians and scientists as *botanists*,[31] as did also the analysis of the prosopographical dictionaries of the different periods of Byzantine history published over the past decades.[32]

27 Diels (ed.), *Die Handschriften der antiken Ärzte*, vol. 1: *Hippokrates und Galenos*; *Die Handschriften der antiken Ärzte*, volume 2: *Die übrigen griechische Ärzte auser Hippokrates und Galenos*; with a supplement (presented as the first, but not followed by any other): *Bericht über den Stand des interakadmischen Corpus Medicorum Antiquorum und Erster Nachtrag zu den in den Abhandlungen 1905 and 1906 veröffentlichten Katalogen*.

28 Currently available catalogues of Greek manuscripts are listed in Olivier, *Répertoire des bibliothèques et des catalogues de manuscrits grecs*, recently complemented (2018) with a *Supplément au Répertoire des bibliothèques et des catalogues de manuscrits grecs.*

29 For specific catalogues, see for example Bazzi, *Catalogo dei manoscritti e degli incunaboli di interesse medico-naturalistico dell'Ambrosiana e della Braidense*, about the Ambrosian and Braidense libraries in Milan, or *Immagine e Natura. L'immagine naturalistica nei codici e libri a stampa delle Biblioteche Estense e Universitaria* about the manuscripts at the Biblioteca Estense e Universitaria in Modena. For a general census of medical medieval illustrated manuscripts in all languages, see MacKinney, *Medical Illustrations in Medieval Manuscripts*, which includes several items in Greek. For the scientific illustrated manuscripts in the collection of the Bibliothèque nationale de France in Paris, see Lazaris, "Inventaire sommaire des manuscrits grecs scientifiques illustrés de la Bibliothèque nationale de Paris."

30 For the resulting inventory of manuscripts, see Touwaide, *A Census of Greek Medical Manuscripts*.

31 See Samama, *Les médecins dans le monde grec: sources épigraphiques sur la naissance d'un corps médical,* mostly on Classical antiquity, but going up to the 6th century CE; and Nissen, *Prosopographie des médecins de l'Asie mineure pendant l'Antiquité classique*, focussing on the Classical world, though expanding until the 5th century CE.

32 For the period ca. 300–ca. 1500, see Savides/Hendrickx (eds.), *Encyclopaedic Prosopographical Lexicon of Byzantine History and Civilization*; for the period 641–867, see Lilie et al. (eds.), *Prosopographie der mittelbyzantinischen Zeit. Erste Abteilung; for the period 867–1025*, see Lilie et al. (eds.), *Prosopographie der mittelbyzantinischen Zeit*. Zweite Abteilung; and for the period 1261–1453, see Trapp et al. (eds.), *Prosopographisches Lexikon der Palaeologenzeit*.

Data extracted from textual sources can be confirmed by the constantly growing body of archaeobotanical material recovered from excavation sites around the Mediterranean. After pioneering decades, archaeobotanical studies are yielding an increasing amount of material from plants themselves (entire or in fragments) to their traces. Entire plants and fragments, which include residues of food and alimentary products in containers of all kinds and waste recovered from pits, for example, usually allow for visual identification. Traces, instead, can be identified only by specialized laboratory analysis. They are composed of pollen and phytoliths in soils,[33] residues (digested or not) in human feces and animal dung, and traces of products in soils, containers and all types of archaeological remains, including human skeletons and organs. Identification requires sophisticated instrumentation in a sterile laboratory (to avoid contamination) and high-technology methods that are difficult to apply, are expensive, and do not necessarily yield as much data as might be expected. This is particularly the case with ancient DNA identification, known as (a) DNA.[34] Though technically possible, it is hampered by several obstacles including contamination, be it *in-situ* or by the archaeologists themselves. This happened often with material collected before the development of biomolecular archaeology and, consequently, awareness about the information it may generate. When DNA is available, it is often fragmented. Extraction requires cutting-edge techniques and related instrumentation, in addition to sequences of base pairs long enough to be indicative of botanical species.[35] In any case, results need to be carefully interpreted. Containers yielding (a)DNA, for example, might have been reused, something that interferes with the results by collapsing in a certain sense the time period(s) during which the identified products were present in the containers under analysis.

The archaeobotany of this type can be defined as *micro-archaeobotany* or the *archaeology of the invisible*. It marries with *macro-archaeobotany*, dealing with environment, oro-hydrography and geomorphology, forest cover or, conversely, deforestation, and land occupation.

33 On phytoliths, see Piperno, *Phytoliths*.

34 On this, see Travis, "Archaeologists See Big Promise in Going Molecular," reporting about the 2010 edition of the biennial International Symposium on Biomolecular Archaeology (ISBA).

35 For an example of this type of research see the identification of the plant components in the so-called Roman pills recovered from the shipwreck traditionally identified as the *Relitto del Pozzino* in the Baratti Gulf in Italy, at Piombino on the coast of Tuscany (Italy). See the following report on the Internet: <https://medicaltraditions.org/institute/news/168-research-breakthrough-2000-year-old-medicine-revealed>.

Written scientific information and physical evidence are usefully complemented by literary sources (descriptions of gardens, for example), legal documents (foundations acts [*Typika*] of monasteries prescribing among other things the planting of gardens), taxation tables (listing items liable for taxes, including foodstuffs and medicinal plants, together with the size of those taxes), scientific representations of plants (as taxonomical devices in relevant works), plant elements in architecture and architectonic structures, and flowers, trees, and vegetal landscapes in major and minor artistic creations from miniatures in books, jewels, cameos, and carved ivory pieces of art, for example, to frescoes and mosaics in architectural components.

Combined data must be carefully scrutinized bearing in mind the many components that contribute to the making of botany, from phytogenesis to taxonomy, including floristic inventories and descriptions, biodiversity, the introduction of new species into non-native environments and, conversely, the extinction of species, the seasonal life cycle of plants, and occasional or pluriannual natural phenomena such as severe winters, episodes of drought or exceptional flooding, man-made alterations of the environment, phytosociology and phytopathology, horticulture and agriculture.

In the absence of both a survey of botany in Byzantium and the lack of specific studies, any research into the history of the subject must start with the classical general histories of science,[36] the review of sources compiled by Herbert Hunger (1914–2000) forty years ago,[37] entries in the *Oxford Dictionary of Byzantium*,[38] the *New Pauly*,[39] and the *Encyclopedia of Ancient History*,[40] or more recent encyclopedias and dictionaries of ancient and medieval science.[41] Complementary information on the tradition of Byzantine botanical treatises in the Syriac and Arabic worlds can be found in the two contemporary compilations by Fuat Sezgin (1924–2018) and Manfred Ullmann,[42] to be complemented

36 For example, Sarton, *Introduction to the History of Science*, or Thorndike, *A History of Magic and Experimental Science*.

37 Hunger, *Die hochsprachliche profane Literatur der Byzantiner*, vol. 2, pp. 271–76.

38 Edited by Alexander Kazhdan (1922–1997).

39 The work was originally published in German from 1996 in 13 volumes, with an index and 7 supplements thus far. English translation entitled *Brill's New Pauly*, 16 volumes and supplements, 2002–2018.

40 Bagnall et al. (eds.), *Encyclopedia of Ancient History*.

41 Keyser/Irby-Massie (eds.), *Encyclopedia of Ancient Natural Scientists; The Greek Tradition and its Many Heirs*, and Glick/Livesey/Wallis (eds.), *Medieval Science, Technology, and Medicine: An Encyclopedia*.

42 Sezgin, *Geschichte der arabischen Schrifttums*, vol. 4: *Alchimie, Chemie, Botanik, Agrikultur*, and Ullmann, *Die Natur- und Geheimwissenschaten im Islam*.

with the second edition of the *Encyclopedia of Islam*,[43] the *Encyclopaedia Iranica* (also available on the Internet in open access),[44] and, more recently, encyclopaedias as *Medieval Islamic Civilization – An Encyclopedia*,[45] and *The Oxford Encylopedia of Philosophy, Science, and Technology in Islam*.[46]

## 4 The Botanical Tradition

### 4.1 *A Short Survey of the Current State of Research*

The study of the history of botany was traditionally concerned with the production of new treatises and their contribution(s) to botany. The analysis of illustrated manuscripts of Dioscorides, *De materia medica*, was no exception, as it was usually devoted to searching for new plant representations and naturalistic images possibly resulting from personal observation.

From mid-20th century to present day, the textual history of the treatises under consideration here has been researched in a variety of ways. The textual tradition of the *Corpus Hippocraticum*[47] and *De plantis* attributed to Aristotle has been extensively investigated.[48] This is also the case, though to a lesser extent, for both treatises by Theophrastus: inventories of manuscripts have been compiled,[49] their linkages have been determined to build a *stemma codicum* for critical editions of their text, and the history of the diffusion of

43 Bearman/Bianquis/Bosworth/van Donzel/Heinrichs (eds.), *Encyclopaedia of Islam, Second Edition*, with a third edition in progress: Fleet/Krämer/Matringe/Nawas/Rowson, *Encyclopaedia of Islam Three*.

44 Yarshater (ed.), *Encyclopaedia Iranica*.

45 Meri (ed.), *Medieval Islamic Civilization-An Encyclopedia*.

46 Kalin (ed.), *The Oxford Encyclopedia of Philosophy, Science, and Technology*.

47 Besides the introduction to the critical edition of the many Hippocratic treatises, see, for example, Irigoin, "Tradition manuscrite et histoire du texte. Quelques problèmes relatifs à la Collection Hippocratique"; Idem, "1987–1988 Hippocrate et la Collection hippocratique"; and Idem, "1988–1989 Hippocrate, Galien et quelques autres médecins grecs." For *De victu* more specifically, see the history of the Greek text in the editions mentioned above (p. 305, note 7) and also, for the Latin translations and derivatives, the list of manuscripts in Kibre, *Hippocrates Latinus*, pp. 124–28 (*De cibis*), 195–96 (*Nutrimentum*), and 230–31 (*De victus ratione*).

48 See mostly Drossart Lulofs/Poortman (eds.), *Nicolaus Damascenus "De plantis."*

49 In addition to the editions above p. 306, notes 10–12, see (in chronological order) Wilson, "The manuscripts of Theophrastus," and Einarson, "The manuscripts of Theophrastus' *Historia Plantarum*."

Theophrastus' works in the Middle Ages (not only *Historia plantarum* and *De causis plantarum*) has been reconstructed.[50]

The case of Dioscorides, *De materia medica*, is rather different. After the German scholar and historian of medicine, Max Wellmann (1863–1933), at the beginning of the 20th century reconstructed its textual history on the basis of *c.* 30 manuscripts, and provided a critical edition that is, to this day, a standard work of reference, there was then little new research for several decades. Wellmann's work, being almost the only one available, has been widely diffused in 20th-century scholarly literature. Only during the closing decades of the 20th century did fresh research begin. The so-called *American School of the History of Pharmacy* opened the way in the late 1960s with a particular interest in the Latin version of Dioscorides.[51] Slightly later (in the late 1970s) and collaterally, I began studying the history of the text of the two treatises on venoms and poisons attributed to Dioscorides and presented as his *books* 6 and 7 (or 6–9, with *book* 7 divided into three *books*).[52]

Further activity explored three different traditions of *De materia medica*: the Latin translations and adaptations,[53] the Arabic manuscripts, translations,

50 Schmitt, "Theophrastus in the Middle Ages," and "Theophrastus." See also the *Theophrastus Project* aimed to reconstruct the fortuna of all Theophrastus' work, particularly vol. 5 edited by Sharples, *Theophrastus of Eresus*.

51 Research in this direction was launched as early as the mid-1960s by Jerry Stannard (1926–1988) who focussed on the Renaissance in the following articles: "Dioscorides and Renaissance Materia Medica," "P.A. Mattioli and some Renaissance Editions of Dioscorides," and "P.A. Mattioli: Sixteenth Century Commentator on Dioscorides." He was soon followed by John Riddle, with several articles among which the following: "The Latin Alphabetical Dioscorides Manuscript Group" dating to 1971, and "Pseudo-Dioscorides' *Ex herbis feminis*" of 1981. Between these two articles, Riddle published a vast compilation on the different Latin versions of *De materia medica* in the *Catalogus Translationum et Commentariorum* under the title *Dioscorides*, in which he offered a first essay on the history of Dioscorides' text from its first version to the end of the Renaissance (pp. 4–23).

52 Touwaide, *Les deux traités toxicologiques attribués à Dioscoride*, for the PhD thesis, with the following articles presenting some of its conclusions: "L'authenticité et l'origine des deux traités de toxicologie attribués à Dioscoride" and "Les deux traités de toxicologie attribués à Dioscoride – Tradition manuscrite, établissement du texte et critique d'authenticité."

53 Riddle's research has been taken over by Arsenio Ferraces Rodriguez, for example, in his *Estudios sobre textos latinos de fitoterapia*, where he analyzes the Latin translations of *De materia medica* (see pp. 171–224, 225–67, and 327–56). Some more recent work returned to this topic (Cronier, "Le Dioscoride alphabétique latin" and "Pour une étude du *Dioscoride alphabétique* latin").

and terminology,[54] and, lastly, the Greek tradition,[55] together with new work on papyri, including a re-examination of the so-called Michigan papyrus,[56]

54 For a review of the scholarly research on the so-called *Dioscorides arabicus* until 1996, see Touwaide, "La traduction arabe du *Traité de matière médicale* de Dioscoride: État de recherche bibliographique." In chronological order in each of the topics above, see (manuscripts): Grube, "Materialien zum Dioskurides Arabicus"; Sadek, *The Arabic Matera Medica of Dioscorides*; Touwaide, *Farmacopea araba medievale. Codice Ayasofia 3703*; Labarta, "Un nouveau manuscrit de la version arabe de la 'Materia Medica' de Dioscoride"; Shafqat Azmi/Mehdi/Shamsi, "Some Salient Features of 'Kitabul-hashaish' with Special Reference to the Manuscript Preserved in Khuda Baksh O.P. Library, Patna," and Touwaide, "Persistance de l'hellénisme à Bagdad au début du XIII^ème^ siècle. Le manuscrit Ayasofia 3703 et la politique abbasside"; (translations): Dubler/Teres (eds.), *La 'Materia médica de Dioscorides. Transmisión medieval y renacentista*, vol. 2, which contains an edition of one of the Arabic versions of the text; Touwaide, "L'intégration de la pharmacologie grecque dans le monde arabe. Une vue d'ensemble" followed by a more recent philological analysis by Ullmann, *Untersuchungen zur arabiscehn Überlieferung der* Materia medica *des Dioskurides*; (terminology): Albert Dietrich, with the following three major works: *Dioscurides Triumphans*; *Die Dioskurides-Erklärungen des Ibn al-Baitar*; and *Die Ergänzung Ibn Gulgul's zur Materia medica des Dioskurides*.

55 The 1935 pioneering study by Kourilas, *Διοσκοριδείοι Μελέται καὶ ὁ Λαυριωτικός Διοσκορίδης*, was not followed by any, as was not either Buberl, *Die Byzantinische Handschriften 1. Der Wiener Dioskurides und Die Wiener Genesis*. After some work in the 1950s and 1960s, sporadic relevant publications included Gerstinger, *Dioscurides, Codex Vindogonensis med. gr. 1 der Österreichischen Nationalbibliothek*, and Kritikos/Athanasoula, "Οἱ ἐν Ἑλλάδι εὑρισκόμενοι Φαρμακευτικοὶ Κώδικες. I. Ἀθωνικοὶ Κώδικες τοῦ Διοσκουρίδου (Δημοσίευμα 1^ον^)," which remained the only issue of this programme. It was only in the 1980s that research started with the following works, very different in nature (chronological order of publication): Riddle, "Byzantine Commentaries on Dioscorides"; Touwaide, "Un recueil grec de pharmacologie du Xe siècle illustré au XIVe siècle"; Idem, "Les manuscrits illustrés du *Traité de matière médicale* de Dioscoride"; Χριστόδουλος, "Ὁ Ἀθωνικὸς κώδ. Μεγ. Λαύρας Ω 75 τοῦ Διοσκορίδη"; Touwaide, "Un manuscrit athonite du *Traité de matière médicale* de Dioscoride: l'*Athous Magnae Laurae* Ω 75"; Idem, "Le Traité de matière médicale de Dioscoride en Italie"; Luccioni, *La postérité de l'oeuvre de Dioscoride* (unpublished PhD thesis, which the author generously shared with me); some articles by Cronier: "Quelques aspects de l'histoire du texte du *De materia medica*," "L'herbier alphabétique," "La production de manuscrits scientifiques," and "Un manuscrit méconnu du περὶ ὕλης ἰατρικῆς de Dioscoride"; finally, also Faraggiana di Sarzana (ed.), *Il codice 3632*. Marie Cronier has devoted to *De materia medica* a 2007 PhD thesis still unpublished and not available for consultation. Based on the articles above, it seems that she built on the renewed interest in Dioscorides over the past decades, though often doing it tacitly. Whatever the case, judging from her published studies, her work is primarily philological in nature, and only aims at a critical edition of Dioscorides' Greek text as the title her 2008 article makes plain: "L'apport de la traduction arabe de Stéphane à l'établissement du texte grec du *De materia medica* de Dioscoride."

56 Flemming/Hanson, "Dioscorides, *De materia medica* II 76.2 and 76.7–18."

and the very recent critical edition of Oxyrhynchus papyri that had remained unpublished.[57]

Though the research is still rather scant, it has shown that the number of manuscripts of *De materia medica* is much higher than previously thought, and that Wellmann privileged a lineage of manuscripts that does not necessarily contain the most plausible version of the text, besides neglecting or underestimating some manuscripts which were subsequently discovered to be important. Wellmann's edition is now in need of revision, particularly because the concepts of textual history and ecdotic on which it was based, strictly mechanicist and linear in nature, no longer correspond to those of current research on textual transmission. My own work revealed, for example, that many manuscripts merged not only specific readings, but also entire segments of the *De materia medica*, borrowed from codices different from their model. Also – and more significantly from our viewpoint here – copyists, who were probably physicians, sometimes transformed *De materia medica* by introducing data resulting from their personal experience of pharmacotherapeutics.

For Galen's treatise *De simplicium medicamentorum temperamentis et facultatibus* (*On the mixtures and properties of simple medicines*), the available edition by Kühn needs extensive revision, mostly because it reproduces an earlier text and, through it, printed editions dating back to the Renaissance. Fresh research started very recently,[58] with an inventory of the manuscripts containing the work,[59] and a first ébauche of its tradition.[60] For the moment at least, one of the major results of this ongoing programme has been to distinguish the tradition of the two major parts of the treatise. The decipherment of the so-called *Syriac Galen*, that is, the several folios of a Syriac translation of the treatise possibly dating to the 6th century in a palimpsested manuscript, is expected to renew knowledge of the tradition of the work.[61] The Arabic translation has not yet been explored in detail.[62]

57 Leith, "Dioscorides" published in 2014.

58 Bouras-Vallianatos/Zipser (eds.), *Brill's Companion to the Reception of Galen*, does not touch upon the topic of Galen's view(s) on botany in Byzantium.

59 Petit, "La tradition manuscrite du traité des *Simples* de Galien," which contains some misidentification and incorrect locations of codices.

60 See Petit, "Théorie et pratique," and also Eadem, "Galen's Pharmacological Concepts," which is not limited to the content announced by the title, but includes a prototype for a new edition of a chapter of the second part of the work (περὶ ἀγχούσης = VI.α.δ).

61 On the Syriac Galen, see in chronological order: Bhayro, "Sergius of Rešʿayna's Syrica Translations of Galen"; Bhayro/Hawley/Kessel/Pormann, "Collaborative research"; Bhayro/Hawley/Kessel/Pormann, "The Syriac Galen Palimpsest"; and Hawley, "More identifications of the Syriac Galen Palimpsest."

62 For a first examination, see Garofalo, "Un sondaggio."

As for the *Geoponika*, their complex transmission and, beyond that, the prehistory of the text have been repeatedly scrutinized. Research has reached solid conclusions on the gradual making of the collection and on the diffusion of the text, even though several previously undetected manuscripts have been recently brought to light.

Finally, for the texts resulting from the translation into Greek of works originally in Arabic or Persian, only the tradition of the treatise of Symeon Seth has been investigated, if in an incomplete and possibly inaccurate way.[63] Some other pioneering studies have been published, particularly by the Greek historian of medicine Aristotelis Kouzis (1872–1961), which, however, have not been followed by many others.[64] Many of the other texts, even though some of them have long been known to have existed, have not yet been critically edited and studied.

## 5 The Natural Environment and Flora of Byzantium

The environment and vegetation in the territory covered by the Byzantine empire, in all time periods, was mostly Mediterranean, with all the sub-environments characteristic of the Mediterranean world, from sea-shore to mountains. At its largest expansion under Justinian in the 6th century, the Byzantine territory was bordered by different environments: the Caucasus and the Iranian plateau to the East, the Arabic and African deserts to the South, the Atlantic Ocean beyond the Pillars of Hercules in Southern Spain, and the Alps and the Danube, with the Black Sea to the North. Each of these environments had – and still has – its own typical climate and vegetation.

The current Mediterranean environment is most probably ancient as the study of the native distribution of plants indicates, combining Linnean taxonomy and Darwinian evolutionary thinking. Research into the origin of plants was initiated by the Franco-Swiss botanist Alphonse Pyrame De Candolle (1806–1893), author of *Origine des plantes cultivées*.[65] Following in De Can-

63 See Langkavel (ed.), *Simeonis Sethi Syntagma de alimentorum facultatibus*, pp. iii–v, with a critical analysis in Helmreich, *Handschriftliche Studien zu Symeon Seth*. New manuscripts have been identified since.

64 Among the articles by Kouzis see, for example, "Quelques considérations sur les traductions en grec des oeuvres médicales orientales." An exception to this lack of studies is Harig, "Von den arabischen Quellen des Simeon Seth."

65 De Candolle, *Origine des plantes cultivées*. The *Préface* (pp. vii–viii) is dated "1er septembre 1882" (p. viii), something that led bibliographers to consider that the book was published in 1882 and not in 1883 as per the title page.

dolle's footsteps, the Russian botanist Nikolai Ivanovich Vavilov (1887–1943) compiled a similar work originally published in Russian in 1940, but not translated into English until 1992 under the title *Origin and Geography of Cultivated Plants*.[66] Vavilov created the concept of *centres of origin of plants*, that is, loci where plant species originated in the millennia-long evolutionary story of the natural kingdom. He identified eight such centres worldwide, with the Mediterranean being one of them. Similar work was further done by the Armenian-born scientist Armen L. Takhtajan (1910–2009), who developed Vavilov's concept of *centre* into *floristic region*. Takhtajan's seminal work was first published in Russian in 1961 and translated into English as early as 1969 under the title *Floristic Regions of the World*.[67] The Mediterranean was among Takhtajan's floristic regions that were home to multiple botanical species.

Whereas research of this type was based on locating wild individuals of botanical species, more recent research proceeds by genetical analysis, which results in reconstructing the long-term history of plants in the form of phylogenetic trees.[68] In most cases, such reconstructions include the geographic origin of the families under consideration, most often in terms of continents or major regions of the world, but sometimes also in a more circumscribed way in terms of historical periods.[69] Though it is certainly useful for deep-time exploration of the creation of a botanical environment, this method does not necessarily account for more recent, historical phenomena. A case in point is that of *Datura stramonium* L. (Jimson Weed or Thorn Apple, Solanaceae), clearly attested in antiquity; yet it is considered typical of the New World and was supposedly transferred to the Old World after the 1492 arrival of the Europeans returning from the Americas (see below, pp. 327–328). An increased amount of evidence has led to a possible revision of the traditional division of flora between Old and New Worlds or, at the very least, to a chronological recalibrating of the history of plant transfers between the two Worlds. Consequently, the plant range of the Old World may be larger and more diversified than previously thought.

66 Vavilov, *Origin and Geography of Cultivated Plants* was first published in Russian in 1987 in Leningrad as *Происхождение и география культурных растений*.

67 The work was originally published as *Флористические области Земли* in Leningrad.

68 On this, see de Queiroz/Gauthier, "Phylogeny as a Central Principle in Taxonomy," and de Queiroz, "Phylogenetic definitions and taxonomic philosophy."

69 For an example of such method, see Olmstead et al., "A molecular phylogeny of the Solanaceae."

### 5.1 *Environmental Awareness*

It does not seem that Byzantine scholars developed a concept of either a Mediterranean botanical unity or a regional diversity. Some such a concept is explicitly present in the *Hippocratic corpus* in the treatise *De aeribus, aquis et locis* (*Airs, Waters, Places*) possibly dating to the late 5th century BCE, where the principle of environmental specificity is stated. However, it might have been a theorization of facts possibly observed empirically and summarized in an abstract way (with all the environmental characteristics that contribute to create certain types of environments, together with their impact on human health), rather than a geographical map with precise areas identified by their environmental specificity, including their flora.

Some botanical species were identified by a place name. For example, in *Historia plantarum*, Theophrastus identified some plants as typical of Crete, and, in *De materia medica*, Dioscorides explicitly stated a local origin for several botanical species. It does not seem, however, that these geographical references reflect a conceptual theorization similar to those of *centre of origin* or *floristic region*. They refer, instead, to the areas producing individuals with the best organoleptic or therapeutic qualities of the species under consideration thanks to particularly favourable climatic conditions (as in the case of Crete), or to areas where the Greek speaking world came into contact with species that were not originally native to the Mediterranean environment. The former would attest to an empiric experience of differences in the sensory perception of plants (taste and scent) and possibly also in induced therapeutic action, rather than hinting at a concept of native distribution non-explicitly stated.

Paradoxically enough, awareness about floristic specificity in both antiquity and Byzantium seems to have existed about exotic species, that is, species non-native to, but introduced at some point in time into, the Mediterranean environment. A precedent for this might be Alexander the Great's expedition to India and the reports on the flora of the different regions that Alexander's troops crossed, reports made by the scientists accompanying the military corps.[70] These and other similar surveys became a source of literary inspiration that meshed the exotic and the fantastic. The resulting genre might be best illustrated by the collection known as the *Cyranides*, possibly first assembled in the 4th cent. CE.

70 On the plants discovered by Alexander's troops, see Bretzel, *Botanische Forschungen des Alexanderzuges*.

### 5.2 *Biodiversity*[71]

An important characteristic of the Mediterranean environment, particularly of its Eastern part, is its high level of biodiversity.[72] This wide variety of species – not only plants, but also animals and even microbes[73] – led to the Mediterranean region being identified as a *biodiversity hotspot* in contemporary natural science.[74]

The current high density of species is not, as some current genetic modifications might suggest, the result of a rapid increased speciation in recent times, but, as the study of the origin of plants indicates, is most probably an ancient fact.[75] Analysis of the process of plant domestication, mostly based on archaeological remains, confirmed the role played by the Mediterranean region in the transformation of botanical species from wild to domesticated species and, by way of consequence, the configuration of the vegetal cover of the region, with all its variety.[76]

Considering that current Mediterranean plant diversity reflects with some plausibility its ancient state, botanical species currently identified in the Mediterranean environment are more numerous than they were believed to be in ancient times. This is not because speciation increased, but rather because

71 On this term, created by Water G. Rosen, see Wilson, "Editor's Foreword," p. vi, in the volume of proceedings of the National Forum on BioDiversity held in Washington, DC, September 21–24, 1986 (= Wilson/Peter [eds.], *Biodiversity*).

72 See for example and in chronological order: (1996) Cowling et al., "Plant diversity in mediterranean-climate regions"; (1999) Mittermeier et al., *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*, pp. 254–67; (2001) Grove/Rackham, *The Nature of Mediterranean Europe*, pp. 45–47.

73 See for example and recently (2014, about land microbe biodiversity) Siles et al., "Microbial Diversity of a Mediterranean Soil," and (2015, about sea microbe biodiversity) Luna, "Diversity of marine microbes in a changing Mediterranean Sea."

74 On the Mediterranean as a hotspot for plant diversity, see in chronological order: (1998) Mittermeier et al., "Biodiversity Hotspots and Major Tropical Wilderness Areas"; (1999) Mittermeier et al., *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*; (2000) Myers et al., "Biodiversity hotspots for conservation priorities"; (2004) Mittmeier et al., *Hotspots Revisited. Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*, and Comes, "The Mediterranean region. A hotspot for plant biogeographic research." On Mediterranean marine biodiversity, see for example Coll et al., "The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats." On the characteristics of the Mediterranean climate and plant cover, see Dallman, *Plant Life in the World's Mediterranean Climates*, pp. 1–57.

75 See above, pp. 317–318, the works by De Candolle, Vavilov, and Takhtajan.

76 On this topic, see the most recent edition (the 4th) of the classical work by Zohary and Hopf, first published in 1988: Zohary/Hopf/Weiss, *Domestication of Plants in the Old World*. More generally, see Colledge/Conolly, *The Origins and Spread of Domestic Plants in Southwest Asia and Europe*.

ancient species can – and do – correspond to more than one modern species thanks to more refined methods of identification in current botanical taxonomy, which allow for a better differentiation of species within genera.

There is no clear trace of a possible explicit awareness about the botanical richness of the Mediterranean region in antiquity and Byzantium. Specialized knowledge of materia medica in Cilicia might hint at some sort of such awareness, but this might have been just in an implicit form. Judging from the number of specialists in materia medica and therapeutics linked with Tarsus, it has been supposed that the city, once the capital of the Roman province of Cilicia, was the seat of a pharmaceutical school.[77] Furthermore, Dioscorides was native to Anazarba, not far from Tarsus.[78] As he himself stated, he had been interested in the topic from his early years,[79] possibly encouraged by the lush vegetation of his hometown. Both Tarsus and Anazarba were located in the Cilician plain, a region with the highest density of biodiversity in the Mediterranean basin. Located in the south east of the Anatolian plateau, Cilicia is bordered by two mountain chains, the Amanos (now Nur Mountain) to the east and Taurus to the north, both of which contribute to the making of an enclosed environment. Furthermore, the plain is crossed by three rivers, which make it particularly fertile.

### 5.3 *Climate and Plant Cover*[80]

Biodiversity might have been under severe stress in some periods because of major, long-term changing climatic conditions. As a result, some species might have had their population reduced, possibly reaching the stage of near-extinction or actual extinction. According to current research the climate possibly went through three phases during the Byzantine period.[81] The so-called

77 See Scarborough/Nutton, "The Preface Dioscorides' *Materia Medica*," pp. 192–93.

78 See the title of *De materia medica*, were Dioscorides is defined as ἀναζαρβεύς. Hardy/Totelin, *Ancient Botany*, p. 39, state that "Galen … was familiar with his native Cilicia …"; similarly, p. 103: "Galen … added much personal information, in particular relating to synonyms from his own region of Cilicia …." This information is incorrect as Galen was native to Pergamon. It probably results from a confusion with Dioscorides.

79 See the *Praefatio*, § 4 = Wellmann ed., *Pedanii Dioscuridis Anazarbei de materia medica libri quinque*, vol. 1, p. 2, ll. 16–17 (= p. 3 in Beck, *Pedanius Dioscorides of Anazarbeus, De materia medica*).

80 For the plant cover in the Byzantine period, see a general description in Grove/Rackham, *The Nature of Mediterranean Europe*, pp. 175–79, which proceeds by regions clockwise from Spain to Crete.

81 The major work on this question is Telelis, *Μετεωρολογικά φαινόμενα και κλίμα στο Βυζάντιο*. See also by the same "Climatic Fluctuations in the Eastern Mediterranean and the Middle East CE 300–1500 from Byzantine Documentary and Proxy Physical Palaeoclimatic Evidence. A Comparison," and chapter 5 of this volume.

"Roman Climatic Optimum" of the period 400 BCE to 500 CE,[82] was followed by the "Dark Ages Cold Period" of the three centuries 500 to 800. The five next centuries (800–1300) constituted what is called the "Medieval Warm Period" or "Medieval Climate Optimum," which certainly affected Western Europe and probably also the eastern Mediterranean. Although the climatic conditions of the period following *c.* 1300 are less clear, they point to colder episodes during the years 1320–1400 and 1430–1450, and a wet period during the years 1340–1390, all of which might be subsumed under the general concept of the so-called "Little Ice Age" after 1300.

The environment and, consequently, the plant cover were certainly impacted by these changes together with the human population, whose demography fluctuated with expansion and contraction according to climatic conditions (favourable or unfavourable, respectively). Plant cover correlated negatively with population fluctuation, with the forest cover reduced in periods of demographic expansion and increased in periods of demographic reduction. Cultivated land expanded as the population increased and reduced as the population declined.[83]

One corollary of the expansion of cultivated land is deforestation. This topic has been much debated. It is said that ship and building construction, together with energy needs took a heavy toll on forests.[84] Russell Meiggs (1902–1989) claimed that extensive logging led to dramatic deforestation.[85] But, as G.W. Bowersock put it, Meiggs' interest in this topic "arose from the work that Meiggs had carried out during the war [WWII] as chief labour officer in charge of home timber production in the [UK] Ministry of Supply."[86] However, according to Oliver Rackham (1939–2015),[87] his was the viewpoint of a Western timber entrepreneur, which does not apply to the period of antiquity. Within the current state of research, there is no conclusive evidence either way.[88]

82 On climate in the Roman world, see Manning, "The Roman World and Climate."

83 On the relationship between settlement and environment, see, for example, Kouki, "Problems of Relating Environmental History to Human Settlement," and Russo Ermolli/Roman/Ruello, "Human-Environment Interaction." Though both related to classical and late classical periods, and to Jordan and Southern Italy, respectively, they are indicative of the problems and methods in this field of study.

84 On deforestation in antiquity and the early Byzantine period, see, for example: Harris, "Defining and Detecting Mediterranean Deforestation, 800 BCE to 700 CE."

85 See his major contribution to this topic: *Trees and Timber in the Ancient Mediterranean*.

86 See his obituary of R. Meiggs in the *Proceedings of the American Philosophical Society*, 135 (1991), 475–477.

87 Rackham, *Trees, Wood, and Timber in Greek History*.

88 See Grove/Rackham, *The Nature of Mediterranean Europe*, particularly pp. 168–69 and 289–291, about deforestation being postulated, but not supported by evidence. On

The transformation of the plant cover of the land does not seem to be mirrored in Byzantine scientific documentation. It can be traced from land surveys and, indirectly, through data about food supplies (particularly staple crops requiring vast areas of arable land). The most significant source of information on macro-variations in the plant cover of the land, however, comes from the structure of the landscape.

### 5.4 *Plant Communities and Affinities*

A typical element within the Mediterranean environment is the presence of plant communities that contribute to the making of specific landscapes, be they the maquis or the Mediterranean savanna.[89] It does not seem that the Byzantine world had any developed sense of awareness about this. Some knowledge exists about plant affinities (for example vine and elm, poplar, manna ash, and maple,[90] or olive and vine[91]) on the basis of the principle of sympathy and antipathy in nature. This idea is of ancient date,[92] and is represented in a visual form in some botanical illustrations in Latin medieval manuscripts, as for example the copies of the *Tractatus de herbis* in its different forms.[93]

### 5.5 *Variations in Biodiversity*

Even though plant diversity was affected by climatic conditions and possibly also by other factors during the Byzantine period, including wars, it is the population of species that was more probably impacted by the cascade effect of climatic changes and other sources of stress. The fluctuation in human population resulting from these factors possibly impinged on plants in a negative correlation. Increased population represented a threat to diversity because of possible over-exploitation, particularly in the wild where species were sought for therapeutic purposes. Reduced human population, instead, may have

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deforestation more generally (including in antiquity and subsequent periods), see the monumental study by Williams, *Deforesting the Earth from Prehistory to Global Crisis*.

89 On this, see Grove/Rackham, *The Nature of Mediterranean Europe*, pp. 46–50 (among others) on the maquis, and 190–216 (specifically) on the savanna.

90 See for example *Geoponika* 4.1 supposedly from Florentinus (Greek text in Beck ed., *Geoponica*, pp. 103–1-6; English translation in Dalby, *Geoponika*, p. 112).

91 See for example *Geoponika* 9.14 supposedly from Africanus (Greek text in Beck ed., *Geoponica*, pp. 246–47; English translation in Dalby, *Geoponika*, p. 192).

92 For the presence of this concept in Byzantium, see for example *Geoponika* 15.1 supposedly from Zoroaster (Greek text in Beck ed., *Geoponica*, pp. 432–36; English translation in Dalby, *Geoponika*, p. 296).

93 See, for example, the manuscript of London, British Library, Sloane 4016, folio 38 verso, of the 15th century, with a representation of Ivy and a tree (maybe an Oak?).

favoured the diffusion of wild invasive species, and also the return of domesticated species to the wild.

Whereas no information is available about possible invasive species, both written material and archaeological remains document the return of domesticated species to their wild form. This is the case, for example, of the balsamum tree, native to the south of the Arabic Peninsula. In antiquity the tree was introduced into the region that corresponds to the current location of Israel. Acclimation was successful and yielded the production of the precious and expensive resin. The collapse of production facilities in the 6th century suggests that plantations were abandoned and returned to their wild form. After that the plant was no longer present in the Byzantine world, either because no attempt to acclimate it was made or because tentative introductions failed. Its resin then had to be imported at a much higher cost.[94] The case of the jujube tree was similar, although this was characterized by repeated successful re-introductions, the very repetition of which indicates that plantations might have been abandoned or not curated correctly.[95]

Assuming that modifications in biodiversity such as those indicated above actually happened, they are not explicitly reflected in the written documentation and do not seem to be easily traceable. However, it might be the case that lists usually entitled in medical historiography as *De succedaneis* (*On substitution products*), which are also known as *Quid pro quo* lists (*This for That*), might have been a part response to biodiversity changes. Based on the short pseudo-autobiographical narrative that opens the work attributed to Galen, this kind of list has been traditionally interpreted as offering a means to compensate for the temporary or local unavailability of a specific botanical species required for therapeutic purposes[96] It might be, however, that they offered therapeutically equivalent alternatives for species that were no longer available (without necessarily being extinct) or were threatened with extinction and needed to be protected. Such an interpretation, however, might not be exclusive. *Quid pro quo* lists might witness some unease in the use of classical texts in later periods. They might have been devices allowing for flexibility in the use of canonical texts. They made it possible, indeed, to modify the components of formulae for medicines and, at the same time, to maintain both the general structure and the therapeutic effect(s) of the formulae.

94 On the history of balsamum in the Byzantine period, see for example Milwright, "Balsam in the Mediaeval Mediterranean: A Case Study of Information and Commodity Exchange" and "The balsam of Matariyya: an exploration of a medieval panacea."

95 See Touwaide, "The Jujube-Tree in the Eastern Mediterranean."

96 On this genre and for a renewed interpretation, see Touwaide, "Quid pro quo."

## 5.6 *Introduction of Non-Native Plant Species*

As early as 1939, the Greek physician and historian of medicine Aristoteles Kouzis demonstrated that Arabic and Persian medicine and, consequently, also medicinal plants from the environment of the ex-Arabic empire, were present in Byzantium from the late 13th and early 14th century onwards.[97] Almost thirty years later, in his study of the 11th-century Symeon Seth, *De alimentorum facultatibus* (*On the properties of foodstuffs*)[98] the historian of ancient medicine, Georg Harig (1935–1989), pushed the introduction of materia medica back in time (up to the 11th century) together with alimentary plants from the East into Byzantium.

A systematic screening of Greek manuscripts with medical content brought to light a substantial body of texts resulting from the translation into Greek of Arabic and Persian textual material.[99] This process took place both in Constantinople and in Sicily. In Constantinople, there might have been several phases, with a first wave possibly as early as the 10th century and certainly in the 11th, as both Symeon Seth's manual on foodstuffs (*De alimentorum facultatibus*) and the analysis of the history of Dioscorides' text clearly indicate.[100] In Sicily, this process might date back to the 11th/12th century.[101] Then, in Constantinople again, this transfer reached its peak after the recovery of the city in 1261 by the Byzantines, and the Conquest of Baghdad in 1258 by the Mongols.

The plants that may have been introduced into the Byzantine world through this process of transfer are not exactly known. In the current state of the cataloguing of manuscripts and the identification of their texts, it seems indeed, that there is no written documentation before the 13th and 14th centuries that explicitly refers to such a phenomenon. Several texts, however, have been overlooked and many are still unpublished or even unknown, so it is possible that

97 Kouzis, "Quelques considérations sur les traductions en grec des oeuvres médicales orientales."

98 Harig, "Von den arabischen Quellen des Simeon Seth." In the same sense, see also, and more recently: Touwaide, "Arabic Materia Medica in Byzantium during the 11th Century AD and the Problems of Transfer of Knowledge in Medieval Science," with a methodological analysis of circulation of knowledge on the basis of the introduction of Arabic medicine in Byzantium. For the Greek text of Symeon Seth's manual, see Langkavel (ed.), *Simeonis Sethi Syntagma de alimentorum facultatibus*.

99 See Touwaide, *Medicinalia Arabo-Byzantina*. *Première partie: manuscrits et textes*, with a first synthesis in "Arabic Medicine in Greek Translation. A Preliminary Report."

100 Touwaide, "Un manuscrit athonite du *Traité de matière médicale* de Dioscoride: l'*Athous Magnae Laurae* Ω 75." More recently Martínez Manzano, "Una interpolación bizantina de origen árabe en Dioscórides."

101 See Touwaide, "*Magna Graecia iterata*. Greek Medicine in Southern Italy in the 11th and 12th Centuries," and "Medicina Bizantina e Araba alla Corte di Palermo."

they might provide a body of information that will lead to a more complete picture.

There are, however, alternative sources which might be used to trace the presence of non-native plants in Byzantium, such as bilingual lexica of plant names in medical manuscripts, most of which date to the late 13th and the 14th century.[102] These bilingual lexica (Greek, and Arabic or Persian [Farsi]) contain the Arabic and Persian (Farsi) phytonyms written in the Greek alphabet (transliterated, instead of being written with the Arabic and Farsi Abjad, respectively) and adapted to Greek phonetic. Similar lexical material can be found outside Byzantium. One such example is the *Synonyma medicinae, sive Clavis Sanationis* compiled in the 13th century by Simo of Genoa, which offers multiple synonyms of phytonyms and other technical medical terms from different languages (all written in the Latin alphabet).[103] Also, as Jerry Stannard (1926–1988) has demonstrated,[104] tables of taxes are indicative of plant movements.

However, the interpretation of these lexica is difficult. Many of their phytonyms are *hapax legomena* that require skillful linguistic interpretation, together with an extensive knowledge of the two languages in the lexica and their medieval variations[105] Furthermore, it is by no means sure that the Byzantines knew the plants themselves in the form of living, cultivated individuals. It seems rather that they knew only the drugs obtained from plants that they traded, possibly through intermediaries,[106] or from their place of origin (or cultivation) to the Byzantine markets. A case in point is μαλάβαθρον

102 For a list of these lexica (including the list of their manuscripts and, when available, the references to their edition[s]), see Touwaide, "*Lexica medico-botanica byzantina*." For a study of tow such lexica, see Tselikas, "Δύο συναγωγὲς ἰατρικῶν λέξεων καὶ ἰατρικὲς συνταγές." On the use of Arabic in science and medicine in 14th-century Byzantium, see Touwaide, "Arabic into Greek: The Rise of an International Lexicon of Medicine in the Medieval Eastern Mediterranean?"

103 The work is traditionally entitled *Synonyma Simonis Genuensis*. It is known through manuscript copies and has been printed in an incunabulum edition dated 1473.

104 Stannard, "Medieval Arzneitaxe and Some Indigenous Plant Species."

105 For the Byzantine forms of such terms, see Charles du Fresne du Cange, *Glossarium ad Scriptores Mediae & Infimae Graecitatis*, and Trapp (ed.), *Lexikon zur Byzantinischen Gräzität, besonders des 9.-12. Jahrhunderts*. Useful also, though more related to the Latin medieval world, the following two lexical compilations: Daems, *Nomina simplicium medicinarum ex synonymariis Medii Aevi collecta*; Stirling, *Lexicon nominum herbarum arborum fructuumque linguae latinae*.

106 In this sense, see Riddle, "The Introduction and Use of Eastern Drugs in the Early Middle Ages," and subsequently Stannard, "Eastern Plants and Plant Products in Medieval Germany."

(*malabathron*).[107] Whereas the plant does not appear in any illustrated manuscript of *De materia medica* prior to the 11th century, it is represented in the frontispiece pages of the Athos copy of Dioscorides,[108] in an image that corresponds exactly to its equivalent in the Leiden copy of an Arabic translation of Dioscorides.[109] Significantly enough, the representation is limited to the leaf (which is the part used in medicine), instead of being the whole plant; furthermore, in the Greek manuscript, its representation includes two African figures, as markers that indicate that the plant is exotic, and, according to ancient geography,[110] comes from lands at the edge of the inhabited world.

Whatever the object (whether plants or drugs), lexica of this type clearly indicate that plants and plant derivatives were handled in Byzantium by individuals from the different ethnic and linguistic communities that contributed to the make-up of Byzantine society, possibly in ways that changed over the centuries. In this context, these lexica acted as connective devices, allowing trans-community communication that opened the door to exchange of information. A similar phenomenon can be detected in botanical illustration, with the creation of albums that offered only images of plants but no text, thus allowing users of different ethnic and linguistic origins to consult them.

### 5.7 *Old World, New World*

Studies of the native distribution of plants have traditionally drawn a clear line between the flora of the Old and the New Worlds. In this view, New-World plants were introduced into, and known in, the Old World only after the discovery of the New World in 1492.

There is mounting evidence showing that plants traditionally considered typical of the New World were present in the Old World before 1492, blurring

107 The plant appears in Dioscorides, *De materia medica*, Book I, chapter 12 (= vol. 1, pp. 16–17 ed. Wellmann; for the English translation, see Beck, *Pedanius Dioscorides of Anazarbus, De materia medica*, pp. 12–13). The plant is traditionally identified as a species of Cinnamon (*Cinnamum* spp.).

108 See f. 6 recto. For a reproduction, see Touwaide, *Farmacopea araba medievale*, vol. 1, illustration 88, and Touwaide/Appetiti, "Knowledge of Eastern Materia Medica," p. 371, illustration 4. Interestingly enough the four illustrations on this folio seem to be additions.

109 This is manuscript or. 289 of the Leiden, Universiteitsbibliotheek, dated to 1083 CE, where the representation of *malabathron* appears on f. 8 recto. On this manuscript, see Sadek, *The Arabic Materia Medica of Dioscorides*, where a black and white reproduction of the illustration of *malabathron* can be found on p. 126. For a color reproduction, see Touwaide/Appetiti, "Knowledge of Eastern Materia Medica," p. 372, illustration 5.

110 These movements of plants were by no means a new process in the ancient world as such transfers can be traced in the written documentation as far back as the *Hippocratic Collection*. Even at that time, they were not a novelty as they certainly went way back in time thanks to the transfer of goods and persons along the Silk Roads. On this, see Touwaide/Appetiti, "Knowledge of Eastern materia medica."

the clear division previously established in botany.[111] Some New-World plants can be traced, indeed, in the Old World. This is the case of Jimson Weed or Thornapple (*Datura stramonium* L.), in the Solanaceae family, supposed to be native to Mexico or Central America.[112] The plant is clearly described in Dioscorides, *De materia medica*.[113] Although in the current edition Dioscorides' chapter clearly suffered some kind of textual accident (probably a major lacuna that resulted in combining the description of two plants of the same genus[114]), it was maintained through the manuscript tradition of the text in Byzantium instead of having been eliminated as though it referred to an unknown plant. It thus seems that *Datura* might have been known to Byzantine scientists.

## 6 Speculative Botany

Knowledge of plants in Byzantium was a complex field that comprised multiple elements ranging from a reflection on what a plant is to the multiple uses of many plants species in daily life. For the purpose of clarity here, this field is divided into three major parts: speculative, analytical, and utilitarian botany. The first two might be considered as *scholarly* botany, whereas the third is identified as *daily-life botany*. The difference between these two major groups is not the scientific nature of the former two, as opposed to the practicality of the latter, since both groups are equally based on a knowledge of the plants. The difference is rather in the type of knowledge they aimed to produce, with *scholarly botany* being a *reflexive* activity aimed at generating a universally valid discourse, whereas *daily-life botany* is a knowledge *in se* and *per se*, not necessarily implying a definition of itself in any specific way.

111 See Sorensen/Johannessen, *World Trade and Biological Exchanges before 1492*, for a collection of relevant data.

112 Vavilov, *Origin and Geography of Cultivated plants*, p. 215; Takhtajan, *Floristic Regions of the World*, p. 343; Sorenson/Johannessen, *World Trade and Biological Exchanges before 1492*, p. 189.

113 See Book 4, chapter 73, where it appears under the name στρύχνον μανικόν (*struchnon manikon*) (= vol. 2, pp. 231, l. 11–232, l. 16 ed. Wellmann, *Pedanii Dioscuridis Anazarbei de materia medica libri quinque*; for the English translation, see Beck, *Pedanius Dioscorides of Anazarbus, De materia medica*, pp. 277–78). On this point, see Touwaide "*Datura stramonium* L.: Old or New World," published in 1998 and confirmed, subsequently (2007) and independently, by Geeta/Gharaibeh, "Historical evidence for a pre-Columbian presence of *Datura* in the Old World."

114 The two plants are Deadly Nightshade (*Solanum nigrum* L.) and Jimson Weed, both of the Solanaceae family.

## 6.1 *Phytogenesis*

Mythology in classical Greece offered narratives accounting for the creation of several botanical species. These narratives involved gods interacting with humans at different moments of the mythological history. The characteristic pattern involved gods transforming humans into plants. A typical case was the transformation of Narkissos into the plant *narcissus*. These tales were still present in Byzantium, not only through the manuscript tradition of mythographic works such as the *Bibliotheca* ascribed to Apollodorus (b. *c.* 180 BCE) (though probably composed in the first or second century BCE), but also – if only partially – in treatises directly related to botany such as the *Geoponika*.[115] It might be the case that some of these tales were illustrated in antiquity, and that some of these illustrations still circulated in Byzantium.

Christianity introduced a different narrative through *Genesis*. Like the tales of classical mythology, this new narrative, too, was creationist; it situated the appearance of plants in the Christian cosmogony. In this narrative, plants were generated by God in two phases: in Day Three and Day Six.

In Day Three (*Genesis* 1:11–13), God created what might be seen as *superior plants* (the grasses, fruit-bearing trees, and seed-yielding herbs, all of which provided food for humans). As the narrative continues: "For the Lord God had not caused it to rain on the earth, and there was no man to till the ground; but a mist went up from the earth and watered the whole face of the ground." The range of these plants, which can be defined as *spontaneous*, is implicitly defined by the affirmation that follows: "These plants [came] before any plant of the field was in the earth and before any herb of the field had grown." Day-Three plants are neither wild (*plants of the field*) nor cultivated (*herbs of the field*) as indicated in the Post-lapsarian narrative (below). In Day Three, nature grows spontaneously, without harmful and invasive plant species, generating nutritious species.

In Day Six (*Genesis* 2:4–9), God planted a garden and created Adam, and also "every tree … that is pleasant to the sight and good for food," followed by the creation of Eve. Then came the Curse, characterized by *thorns* and *thistles*, and the need to grow the plants to be used for food: "… in toil you shall eat of it all the days of your life. Both thorns and thistles it [= the ground] shall bring forth for you, and you shall eat the herb of the field. In the sweat of your face you shall eat bread" (*Genesis* 3:17–19).

115 See *Geoponika* 11.2 (Laurel), 4 (Cypress), 6 (Myrtle), 10 (Aleppo pine), 15 (Rosemary), 17 (Rose), 19 (Lilly), 22 (Violet), 24 (Narcissus), and 29 (Ivy). For the Greek text, see Beckh (ed.), *Geoponica*, pp. 327–28, 329, 330, 332–33, 334–35, 335–36, 338–39, 340–41, 342, and 344, respectively; for an English translation, see Dalby, *Geoponika*, pp. 235–36, 236, 237, 238, 239, 240–41, 242, 243, and 245, respectively.

This Biblical narrative circulated and was commented on in the *Hexaemeron* by early Christian authors such as Basileios of Caesarea (*c.* 329–379), whose works were abundantly reproduced in the Byzantine world.

The phytogenesis of *Genesis* impacted botanical science as did the earlier pre-Christian concepts of plants. On the one hand, it confirmed the hierarchical model of thinking characterized by a bipolarisation of the plant word, with the spontaneous/positive species of Day Three, and those of Day Six *pleasant to the sight and good for food*, opposed to the post-lapsarian species labour-intensive/weedy, which recalls the division of plants in Dioscorides, *De materia medica*, with the plants coming before the animals (warm, scented, fruit-bearing) and those following them (starting with the cereals).[116] On the other hand, however, the *Genesis* narrative, creationist in nature, does not leave space for evolutionary, transformationist thinking, whatever the sense of the evolution (transition from wild to domesticated or conversely; see below, pp. 334–335, and 339).

### 6.2 *Plant Ontology*

The Byzantine world inherited from antiquity – and perpetuated through the manuscript tradition – different concepts of "plant" generated by typical systems of thinking. According to Plato (428/427 or 424/423–348/347 BCE), plants were created by the gods from a substance similar to that of humans.[117] Since they are living creatures, they are *animals* as does everything that participates in life; thus they deserve to be called *animals*. However, they are a distinct species of animal, characterized by sensitivity to pleasant and unpleasant things in addition to appetite, but not by opinion, reasoning, and intelligence. Plants are always passive, and cannot think for themselves or understand their own nature. They live like animals attached to the ground, immobile and rooted, and do not possess the capacity for autonomous movement.

In Aristotle's work, plants are inanimate (in the etymological sense of the word: *deprived of anima*, that is, of soul). And in this way they were used as a model in animal embryology:[118] animal embryos were like plants (that is creatures without soul) until delivery, becoming *animated* (ensouled) at delivery.

Stoic philosophers modified such definitions by considering that both plants and animals, possessing in themselves a cause of movement, are

116 On Dioscorides' classification of plants, see pp. 334–335.

117 *Timaeus* 77a–b. Edition of the Greek text with facing English translation in Bury (ed.), *Plato IX*, pp. 202–04.

118 See *Generation of animals* V.1 = 778b35. Edition of the Greek text with facing English translation in Peck (ed.), *Aristotle XIII*, pp. 490–91. For a commentary, see Liatsi, *Aristoteles, De Generatione Animalium, Buch V*, pp. 88–89.

sustained by a principle that can be identified as *physics* (that is, *natural*, corresponding to nature) or *soul* depending on the philosophical orientation. In this view, *ensouled* things are moved by themselves when an impression occurs within them, calling forth an impulse. According to this model, plants and their life are explained by *physics*, that is, the possession of a principle of movement that enables them to grow out of themselves.[119]

As for Galen, he distinguished two types of innate breath (physical and psychic), and attributed only physical breath to plants.[120] In *De propriis placitis* (*On my own opinions*), he returned to *Timaeus*, praising Plato for calling plants animals characterized by the capacity of sensation, that is, of distinguishing appropriate and foreign substances. This capacity translates into four faculties in plants: attracting, transforming, expelling, and retaining.[121]

Although these different definitions of the plant in the form of general concepts were transmitted to Byzantium through the texts in which they appeared, they probably became obsolete as the result of the diffusion of Christianity and its phytogenesis. As a result they were moved from actual scientific thinking to some sort of history of science. The resurgence of the Aristotelian *De plantis* in the 14th century, together with a possible recrudescence in the interest in Theophrastus and an intense activity in the study and editing of Dioscorides, *De materia medica* (see pp. 376–378), might suggest, however, an attempt to reintroduce the concepts conveyed by these works into the actual practice of science.

## 7 Analytical Botany

Thus far no original botanical treatise compiled in the Byzantine empire has been identified, and we have no knowledge of that any existed.[122] Con-

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119 For the relevant texts and a commentary, see Long/Sedley, *The Hellenistic philosophers*, vol. 2, pp. 319–21 (texts and notes), vol. 1. pp. 319–21 (English translation).

120 *Introductio* 13.1 (= Kühn 14.726.6–11). Greek text with facing French translation in Petit (ed.), *Galien, Tome III, Le médecin. Introduction*, p. 45.

121 *De propriis placitis* 15. Edition of the Greek text with French translation in Boudon-Millot/Pietrobelli, "Galien resuscité: édition *princeps* du texte grec du *De propriis placitis*," pp. 188–190 (Greek text) and 211–213 (French translation). See also the edition of the medieval Latin translation in Nutton, *Galen, On my own opinions*, pp. 62–63. On this Galenic passage, see Roselli, "Galeno e Plat. Tim. 76e 7–77c 5." For the developments of Galen's theory in the Arabic world, see Das, "Beyond the Disciplines of Medicine and Philosophy: Greek and Arabic Thinkers on the Nature of Plant Life."

122 A short, global evaluation of the contribution of Byzantium to botany can be found in Brunet, "Contribution des médecins byzantins à l'histoire des plantes et à la botanique médicale en France." Similarly, Stannard, "Botany," further substantiated in "The Theoretical Bases of Medieval Herbalism," offers some elements.

sequently, botany in Byzantium mostly relied on the classical works on the topic (above).

### 7.1 *The Place of Botany among Sciences*

According to Dioscorides in the introduction of *De materia medica*, the study of medicines (ὁ περὶ φαρμάκων λόγος), which included the description and identification of the plants to be used as therapeutic agents, is necessary (ἀναγκαῖος), if not indispensable, as an ancillary discipline of therapeutics within the field of medicine.[123] This link between botany and pharmaco-therapeutics or, more generally, with medicine was rescinded by Galen. In his considerations about plant ontology he stated, without elaborating further about the rationale for this idea and without specifying what he understood with the expression *medical philosophy*, that knowledge of plants was not necessary for *medical philosophy*.[124] Be that as it may, this statement implicitly moved plant science (whatever its content) out of the field of medicine and gave it the status of a discipline in its own right. This Galenic conception does not seem to have had much influence in Byzantium, however, and plant knowledge remained absorbed in materia medica.

### 7.2 *The Field of Botany*

Galen's dismissal of the necessity for plant knowledge implied a re-definition of the field and the agenda of botany as a science. According to him, indeed, physicians needed to know only that plants attract what is appropriate (which feeds them) and reject what is foreign. Through this statement he split the unitary Dioscoridean unified field of botany (which included descriptive botany and materia medica) into two distinct fields, and he explicitly defined only materia medica that he limited to the knowledge of the interaction (attraction or rejection) between plants on other substances. In so doing he also implicitly redefined botany as the science devoted to the study of plants by themselves and for themselves, in a way that might be reminiscent of Theophrastus.

Such a radical statement needs to be framed in the context of pharmacotherapeutics in Galen's time. After the political crises of the Roman world in

123 See Dioscorides' text: ὅτι γε μὴν ἀναγκαῖος ὑπάρχει ὁ περὶ φαρμάωκν λόγος, παντί που δῆλον, συνεζευγμένος ὅλῃ τῇ τέχνῃ καὶ τὴν ἀφ᾽ ἑαυτοῦ συμμαχίαν ἀήττητον παντὶ μέρει παρεχόμενος = Wellmann, *Pedanii Dioscoridis Anazarbei de materia medica libri quinque*, vol. 1, p. 3, ll. 22–23; English translation: Beck, *Pedanius Dioscorides of Anazarbeus, De materia medica*, p. 3.

124 See the affirmation "ἀλλὰ μηδὲ τῆς τοιαύτης γνώσεως ἀναγκαίας οὔσης εἰς τὴν ἰατρικὴν φιλοσοφίαν" (p. 190, ll. 4–5 in Boudon-Millot/Pietrobelli, "Galien resuscité: édition *princeps* du texte grec du *De propriis placitis*," p. 190, with the French translation on p. 212.

the 1st century BCE, and the transformation of the Roman Republic into an empire, the stabilization of this newly-created political entity, and the exploitation of its multiple and diversified resources, the population benefitted from unprecedented prosperity leading to dramatic demographic growth. This development translated into an unparalleled urbanization resulting in large cities existing remotely from the natural environment. The procurement of natural substances (particularly plants) for the preparation of medicines was affected because of the distance between the place where the plants grew and were collected, and the place(s) where they were consumed. Fresh plants were replaced by their parts, possibly dried or even processed. In these conditions, prescribing practitioners were no longer required to possess a knowledge of botany because they either took the ingredients needed for the preparation of medicines from stocks they had purchased from drug-providers (*pharmacolopolae* or root-cutters) or referred their patients to these drug-providers acting as *pharmacists*.

Galen's dismissal of plant knowledge as unnecessary in medicine could have had wide ranging consequences. By eliminating plant knowledge from the field of therapeutics, it implicitly reduced the usefulness of Dioscorides' treatise. At the same time, by separating botany from materia medica, it automatically defined botany as the science of plants *sensu stricto*, without relation to medicine.

Neither of these two potential consequences of Galen's concept of botany did happen. As their manuscript tradition clearly indicates Dioscorides, *De materia medica*, was much more widely diffused in Byzantium than Galen, *De simplicium medicamentorum temperamentis et facultatibus* (*On the mixtures and properties of simple medicines*). Although there were repeated attempts to combine the two treatises, the field of materia medica in Byzantium was mostly covered by Dioscorides' work, which, even though the work itself, being a 1st-century CE production, is beyond of the chronological scope of the present survey of Byzantine science, must form our principal source for the knowledge of plant science in Byzantium.

Botany in the form it takes in Dioscorides, *De materia medica*, is mostly the science of plants in relation to human uses (in addition to some veterinary and *economic* applications). From this point of view, it was a diagnostic instrument for the correct identification of species to be collected for therapeutic applications, providing relevant information[125] with a specific technical lexicon.[126]

125 For an analysis of botany in *De materia medica*, see Touwaide, "La botanique entre science et culture au Ier siècle de notre ère."

126 On Dioscorides' lexicon, see Aufmesser, *Etymologish und wortgeschichtliche Erläuterungen zu De materia medica des Pedanius Dioscurides Anazarbeus*.

### 7.3 *Taxonomy*

Besides implicitly defining the place of the plant kingdom in the cosmogony (below), *De materia medica* structured the plant world according to a system of which Dioscorides did not specify the exact nature, even though he explicitly stressed its presence.[127] Analysis indicates that the plant world was organized in the first instance as a hierarchical system defined by the values attributed to plant groups (below), resulting in a *scala mundi* characterized by a progressive loss of positive qualities and, conversely, a gradual transition to the opposite qualities (mostly from coloured, light and warm, to black, heavy, and cold, with the values all such qualities were credited with). Interestingly enough, this macro-structure implicitly conveys a kind of evolutionary thinking, defined by a decline that corresponds to the narrative of Humankind's ages in the classical Greek world as told, for example, by Hesiod.

The group of plants positioned on this *scala* are defined by morphological, organoleptic, and therapeutic characteristics, most frequently in conjunction with each other.[128] The first plant within these groups usually best represents the common characteristic(s) of the group as a whole. It is then followed by other plants on the basis of successive comparisons, shifting from one to the next. Comparisons proceed by similarity and difference, and are botanical (similar structures) and/or pharmaco-therapeutic (similar action and, hence, similar applications). For the latter descriptor, differences are either in the degree of the therapeutic action or in its supposed physiological mode of action, or sometimes in both.

Single species within groups are described according to a template proceeding from the general perception (and classification, according to the Aristotelo-Theophrastean model of four categories of vegetals from trees to herbs) to detailed analysis of morphological parts, aerial and then subterranean, including the environment (when it is significant), particularly when that environment impacts upon the medicinal properties of the plants – above all their degree of intensity.

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127 See *De materia medica*, preface, § 5 = Wellmann ed., *Pedanii Dioscuridis Anazarbei de materia medica libri quinque*, vol. 1, p. 3, ll. 9–11 (= p. 3 in Beck, *Pedanius Dioscorides of Anazarbeus, De materia medica*). On botanico-medical taxonomies, see Ventura, "Classification Systems and Pharmacological Theory in Medieval Collections of *Materia Medica*."

128 In his study of *De materia medica*, Riddle, *Dioscorides on Pharmacy and Medicine*, postulated that the structure of the work was based on "drug affinities." This element is present, indeed, but does not account alone for the classification of plants since botanical morphology is present.

Galen did not reproduce Dioscorides' hierarchical taxonomy in *De simplicium medicamentorum temperamentis et facultatibus* (*On the mixtures and properties of simple medicines*), because he ordered plants according to the alphabetical sequence of their most common names. This is a further consequence of the transformation of pharmaco-therapeutics in his time (to which he contributed a great deal), characterized not only by the acquisition of drugs from the market (rather than collecting them from nature), but also by compounding medicines that mixed together various combined therapeutic properties and degrees of activity.

Though cosmogonic and, as a consequence, possibly immutable, Dioscorides' botanical system is evolutionary, even though it is a reverse evolution characterized by the possible return of domesticated species to their wild form. Interestingly enough, wild and domesticated species of a genus differed by the degree of the property of the genus: wild species were usually credited by Dioscorides with a higher degree of that therapeutic property than the domesticated ones.

### 7.4 *Floras*

Whatever the range of species, no flora understood as a catalographic description of the plant species at any given place at any given point in time, has been preserved in the Byzantine world, and we do not know whether any was compiled. It is generally assumed that Dioscorides, *De materia medica*, was used as a flora. Since Dioscorides himself specified in the preface to his work that he sought to be exhaustive,[129] it is often postulated in the history of science that the range of plants known to, and scientifically studied by, Byzantine scientists was that of *De materia medica*, which, according to ancient botany, amounted to about 1,000 species.

The version of *De materia medica* supposed to be authentic contained about 700 chapters devoted to plants. The number of plants described by Dioscorides is larger since several chapters distinguished different species of the same Dioscoridean genus. The actual number of species is unknown, however, as Dioscorides' treatise, whatever its forms and the range of plants in each of such forms, is limited to the species for which there was a use, mostly therapeutic, but also alimentary, veterinary, cosmetic, or economic.[130] It is highly probable that the species contributing to the environment of antiquity and Byzantium

129 On this point, see the *Praefatio* § 6 = Wellmann ed., *Pedanii Dioscuridis Anazarbei de materia medica libri quinque*, vol. 1, p. 3, ll. 17–18 (= p. 3 in Beck, *Pedanius Dioscorides of Anazarbeus, De materia medica*).

130 The re-arrangement(s) of Dioscorides, *De materia medica* represented by the *Herbal*, characterized by a focus on small plants and, by contrast, the elimination of the trees and

were more numerous than the written documentation indicated. Even though Dioscorides stated in the preface of *De materia medica* that he was widely travelled, he was inevitably unaware of the species of some regions, so that the real picture of the flora of the ancient and Byzantine world was larger than his knowledge suggested. Furthermore, since ancient botany did not distinguish species in as refined a manner as does contemporary botany, the actual flora of the ancient Mediterranean was certainly broader, and its actual number remains unknown.

Archaeobotany could contribute to a better knowledge of the floral diversity in the Byzantine world. To yield statistically valid results, however, analysis will have to be systematically applied to material (macro-remains or traces of plants) coming from a certain number of areas at different periods in their history. Though technically possible, this is, however, something that might be difficult to achieve.

In these conditions, textual material remains the main source in the current state of research, but its data must be considered as only indicative of the flora with which humans interacted. To compensate for the difference between the actual number of floristic species and those used by humans, a comparison could be made on the one hand with traditional groups currently in existence whose both flora and use of plants thanks to an exact floristic inventory are known with some precision, and, on the other hand, a comprehensive recording of their habits through anthropological fieldwork. A ratio might be established between the number of actual species in the area of such a population and the number of the species they use, and this ratio could be extrapolated to the ancient medico-botanical literature.

Until such transdisciplinary historical and ethnobotanical/ethnopharmacological work is done, the range of botanical species known to Byzantine scientists must be evaluated through the massive computerization of textual data. This might lead to plausible approximations and identifications by genera and/or species, on the assumption that the quantity of accumulated material might generate a plausible estimate thanks to the meta-information resulting from the quantity of data. The programme THEOREMA launched as early as the 1980s offered pioneering research of this kind, aiming to sum up all the data collected from the Latin pharmaceutical literature from the 1st to the 10th century.[131] Although the programme has since been interrupted, it gener-

most of bushy plants, is not an indicator of any botanical fact as the selection of the plants preserved in the *Herbal* was determined by therapeutic criteria.

131 See, in chronological order of publication, Delatte/Halleux, "Recettes médicales et ordinateur: le projet THEOREMA"; Halleux-Opsomer/Delatte, "Ancient medical recipes and the computer: the THEOREMA Project"; Halleux-Opsomer, "Le traitement informatique

ated an index of the vegetal materia medica of the Western pre-salernitan Middle Ages (1st to 10th cent.)[132] which might be used as a basis for projections to be tentatively applied to the eastern Mediterranean world during the same period.

### 7.5 *Plant Collections*

Early in the study of the manuscript Vindobonensis medicus graecus 1 (above), it was noticed that some of its plant representations are three-dimensional and create an impression of perspective by generating a sense of depth, in contrast to other representations that are two-dimensional and seem to be flat. These two types of botanical illustration might suggest that the representations of the former group were originally made from nature and personal observation, whereas those of the latter group were made from flattened individuals. If this interpretation of the two-dimensional figures is correct, it implies that, at some point in time, one or more botanical illustrators (who are not those of the Vindobonensis, but of one of its ancestors of unknown date) had access to what modern botany identifies as *dry specimina*, that is, individuals collected in the field that have been pressed, dried, and subsequently mounted onto sheets for consultation.

Such a hypothesis would open new perspectives into the history of botany in classical antiquity and Byzantium. Collections of dry specimina (now identified as Herbaria) are indeed references for both the definition of botanical species[133] and for educational purposes.[134]

### 7.6 *Description of Plants*

In most cases, *De materia medica* provides a description of the plants with which it deals.[135] Such descriptions proceed with some regularity according to a standard pattern including group, genus and species (concepts that are interchangeable in Dioscorides), and the major morphological structures. These start from a general perception of the plant and subsequently proceed in an

des recettes médicales du haut moyen âge"; and Halleux-Opsomer, "Une banque informatisée de pharmacopée ancienne. Pour une histoire quantitative du médicament."

132 Opsomer, *Index de la pharmacopée du Ier au Xe siècle*.

133 Specimina are exact representatives of species and serve as references for the identification of any other individual collected in the field.

134 Being exact representatives of species, specimina allow for the visualization of the characteristic elements (keys) of species.

135 Since *De materia medica* is not a botanical flora *stricto sensu*, it often omits the plant description, particularly for species of which it mentions that they were well known. These were the plants of the natural environment, not those that needed to be precisely identified.

analytical way from superior, aerial, to inferior, subterranean, parts, and move from macro- to micro-structures, that is, from branches to leaves, and to flowers, and from roots to rootlets and external tissue of roots. It concludes with the eco-system typical of the genus/species. Seasonal and environmental variations are included when appropriate.

The identification of the plants mentioned in *De materia medica* according to the current taxonomy has been extensively worked on in post-Linnean botanical history, with a particular focus on classical antiquity.[136] Towards the end of the 20th century, such research has led to a theoretical reflection on methodology.[137] Also, pioneering interdisciplinary programmes were launched bringing together specialists of ancient texts and botanists.[138] Until a method combining all the necessary expertise has been defined and has been applied to as wide a range of material as possible, the identification of plants, in spite of their possible methodological shortcomings, will have to rely on available reference works, preferably by combining them and cross-checking data.[139] The same is valid for the only two available works on Byzantine botany.[140]

136 For a census of publications on the topic (by ancient works), see Touwaide, "Bibliographie historique de la botanique: les identifications des plantes médicinales citées dans les traités anciens, après l'adoption du système de classification de Linné (1707–1778)." Multiple publications have been devoted to single species.

137 See for example, in chronological order: Herzhoff, "Zur Identifikation antiker Pflanzennamen"; Touwaide, "L'identification des plantes du "Traité de matière médicale" de Dioscoride: un bilan méthodologique"; Reveal, "Identifying Plants in Pre-Linnean Botanical Literature"; and Cristofolini/Mossetti, "Interpretation of plant names in a Late Medieval medical treatise."

138 One such programme was about the trees mentioned in Andalusian agronomic literature. See Carabaza Bravo/Garcia Sanchez/Hernández Bermejo/Jiménez Ramírez, *Árboles y arbustos de Al-Andalus*. A similar approach has been applied also to the Naples Dioscorides by a multi-disciplinary group of research bringing together botanists and classicists.

139 See the following works for each of the following periods: (classical antiquity and early Middle Ages): André, *Lexique des termes de botanique en latin*, with a revised edition published almost 30 years later under a new title: *Les noms de plantes dans la Rome antique*; (Byzantium) Langkavel (note 140); (Western Middle Ages and Renaissance) Stirling, *Lexicon nominum herbarum arborum fructuumque linguae*; (Northern medieval Europe) Daems, *Nomina simplicium medicinarum ex synonymariis Medii Aevi collecta.*

140 Langkavel, *Botanik der spaeteren Griechen*, and, more recently, Valiakos/Marselos/Sakellaridis/ Constantinidis/Skaltsa, "Ethnopharmacological approach to the herbal medicines of the "Antidotes" in Nikolaos Myrepsos' Dynameron," the former of which is based on a broad range of textual material, and the latter on the 13th-century *Dynameron* of Myrepsos.

## 7.7 *Macro-Evolution of Plants*

Plato's concept of the plant included some evolutionary thinking. Originally, indeed, plants existed only as wild species, older than cultivated ones. From their cosmogonic genesis to Plato's time, they had been domesticated, "educated" by cultivation, and tamed at the same time as humans.

A similar, though implicit, cosmogonic model can be detected in Dioscorides, *De materia medica*. There, however, the model is more complex, as it includes a hierarchy among the plants discussed above (see p. 334). In this multi-level architecture, *superior plants* (themselves hierarchised from coloured and scented plants to fruit trees) came before animals, and the other plants (which came after the animals and are also hierarchised) came before minerals. This succession seems to result from a cosmogonic system of thinking in which the elements that contributed to the making of the world came into being from animate to inert, in an order defined by the valences with which they were credited.[141]

## 7.8 *Unknown and Extinct Plants*

The textual body used *in lieu* of a flora for the Byzantine world in modern scholarly research – the two works of Theophrastus and *De materia medica* of Dioscorides – include plants that were unknown or might have been extinct. The former is represented by the *molu*, pertaining to the Greek epic tales,[142] and the *toxikon*, while the latter is represented by the *silfion*, which, however, might not have been extinct in Pliny's day.[143] Their continued presence in the body of written documentation illustrates one aspect of the dynamics at play in the transmission of classical texts, the respect for authority, together with the resistance to the modification of texts on the basis of experience.

## 7.9 *Plant Representations*

The polychrome representations of plants that appear in several copies of Dioscorides, *De materia medica*, dating from the 5th to the 16th century and later, have been extensively scrutinized. A major question has been their authenticity: did they go back to Dioscorides or have they been introduced into the manuscripts of *De materia medica* at a subsequent period, in any case anterior to

141 On this hierarchy, see Touwaide, "La botanique entre science et culture au Ier siècle de notre ère."

142 On this plant, see Stannard, "The Plant Called Moly."

143 In this sense, see, for example, Bolens, "Al-Andalus. Plantes nouvelles et plantes retrouvées : l'exemple du silphium."

the most ancient manuscript (5th cent.).[144] The miniature of codex Vindobonensis medicus graecus 1 showing Dioscorides writing *De materia medica* with an artist sitting in front of him and representing a plant (mandrake) has sometimes been considered as a sign that Dioscorides himself might have commissioned the illustrative corpus of his work. An epistemological analysis claims, however, that *De materia medica* could not have been illustrated at the origin, because Dioscorides explicitly stated in his preface that personal observation of the plants at any stage of their life cycle was indispensable for an adequate knowledge of the topic.[145] From this perspective, illustrations in the Byzantine manuscripts were additions, which possibly entered the Dioscoridean opus in the early Byzantine period, and at the latest by the 5th century.

It is a scholarly tradition that the 2nd/1st century BCE physician Kratevas, supposedly physician to Mithridates VI Eupator (132, king 120, 63 BCE), was the first ancient author who illustrated a work on materia medica. It is generally assumed that the plant representations in the Vindobonensis medicus graecus 1 reflect these illustrations of Kratevas. Whatever their origin, there is general agreement that the ancient scientific plant representations were naturalistic, and that they became increasingly schematic through their transmission from one copy to another over the centuries.

A renewed analysis taking into consideration all the illustrated copies of *De materia medica* currently known, instead of focussing on the most achieved de-luxe copies, particularly the codex Vindobonensis, reached a different conclusion. As a result, the interpretations presented above can no longer be accepted. The apparent logic of the thesis according to which Dioscorides *was opposed to plant representations* because he recommended their observation, is contradicted by the practice of botany through the centuries, in which the representation of plants is a diagnostic instrument as equal in value as their textual description.[146] A comparative study of both the text and the

144 See the multiple essays by K. Weitzmann cited here in chronological order of publication, which indirectly implied the existence of plant representations dating back to antiquity, without necessarily attributing them to Dioscorides: *Die byzantinische Buchmarlerei des 9. und 10. Jahrhunderts*; "Das klassische Erbe in der Kunst Konstantinopels"; *Geistige Grundlagen und Wesen der Makedonischen Renaissance*, and *Illustrations in Roll and Codex. A Study of the Origin and Method of Text Illustration*. See also Grape Albers, *Spätantike Bilder aus der Welt des Arztes. Medizin. Bilderhandschriften der Spätantike und ihre mittelalterliche Überlieferung*.

145 Orofino, "Dioskurides war gegen Pflanzenbilder."

146 In this sense, see, for example Orofino, "The Dioscurides of the Biblioteca Nazionale of Naples: the Miniatures," p. 99, where the author states that "the use of pictures, far from being a superfluous luxury, is an essential element for it enables the reader to visualize the object described by the text. Without illustrations, it would a dead work indeed." She

illustrations of *De materia medica* shows that the illustrations exactly represent the morphological structures of the plants mentioned in the text for the identification of specific genera and/or species. The supposed schematic appearance of the plants in the illustrations results from this assemblage of characteristic botanical structures.

## 8 Daily-Life Botany

Speculative and analytical botany as suggested above, which, in a more general way, could be defined as *scholarly botany*, existed together with different forms of plant-related knowledge and activities that could be identified as *daily-life botany*. Contrary to usual practice, these two *botanies* cannot be considered as theoretical vs. practical, as there was no clear-cut difference between theory and practice, each being present and permeating both *botanies*. Similarly, these two forms of botany cannot be opposed as *scientific* vs. *non-scientific*, or *learned* vs. *popular*. Both were equally scientific, but resulted from different forms of science.

*Daily-life botany* was made up of a set of activities that relied on a deep knowledge of the plant world in general and/or of specific plants in particular, with their characteristics and potential for use by humans. *Daily-life botany* here is limited to the major human uses of plants (alimentary, medicinal, and cosmetic), preceded by agriculture.

### 8.1 *Agriculture*

A key issue in *daily-life botany* was the production of plants for human consumption, with relevant techniques. Land ownership was differently managed during the life span of the Byzantine empire. In the ancient Roman tradition land measurement was performed by *agrimensores*, represented in some illustrations of an Athos manuscript.[147] Fencing was indispensable against predators of all kinds, wild or domesticated, including grazing goats and sheep. Fences were possibly made of dry reeds and/or pieces of wood fixed in the ground in the way of palisades, or, more probably, in a natural way, with bushy or taller living species closely planted to act as a defensive wall. Where appro-

nevertheless confirms here (p. 99) the interpretation of her previous article according to which Dioscorides “clearly states that he is against the use of iconographical material.” She attributes (*ibidem*) to Kratevas the innovation of introducing illustrations.

147 See for example an illustration in the *Octateuch* in manuscript Athos, Vatopedi Monastery, 602 (13th century), reproduced in Christou/Mavropoulou-Tsioumi/Kadas, *Οι θησαυροί του Αγίου Όρους: Εικονογραφημένα χειρόγραφα*, p. 86, illustration 134.

priate, such hedging or fencing was made of higher species that also acted as a wind screen.

Whatever the status and availability of the land, agricultural practice was different according to regions (in terms of both orohydrography and localisms), actual places, periods, and traditions. Small scale agriculture to produce food for immediate family consumption in privately owned orchards with some fruit trees or a small fruit-tree grove, sometimes adjacent to dwellings, or perhaps located close to the walls (inside or outside), was probably the most common practice in the countryside and towns. Village gardens/orchards should probably be considered as just an extension of their smaller private equivalents. A similar case, though fundamentally different in its origin, was that of the monastic garden, aimed to provide subsistence to the community that it served. In some instances, monastic gardens might have reached the dimensions necessary for extensive production to satisfy the needs of large communities in the same way as village gardens.

Production for private consumption certainly included basic staples, vegetables, and fruit, in addition to olives for oil and grapes for wine. This kind of production was probably combined with some form of extensive agriculture (possibly in village gardens/orchards) and specialized production, particularly for the cultivation of food staples such as cereals (wheat, barley, oats) and possibly also for vegetables.[148] There is some evidence of specialized production of plants for medicinal uses (see below, pp. 396–397).

Agricultural techniques in small production units were probably transmitted by oral tradition within families or the monastic community, and might have been shared between villagers. The agricultural compilation of the *Geoponika* should not be interpreted as reflecting precisely Byzantine practice since it was mainly a scholarly compilation that went through several phases of editing (see above, p. 308). Nevertheless, it preserved a certain body of data going back to antiquity and late antiquity that was probably still in use in subsequent centuries, with modifications and additions resulting from the experience and consecutive knowledge accumulated through the centuries. In any case, if the techniques described in the *Geoponika* might not exactly reflect Byzantine practice, the topics they covered are those typical of any ancient farm, whatever its size, and agricultural activity around the Mediterranean. In its 20 Books, the *Geoponika* cover a broad range of activities that go beyond

148 See Kenawi/Macaulay-Lewis/McKenzie, "A commercial nursery near Abu Hummus (Egypt) and re-use of amphoras for the trade in plants Egyptian nursery."

agriculture including cattle, pisci- and aviculture, and also animal care and veterinary medicine.[149]

In the *Geoponika*, relevant topics are as follows: the yearly cycle, with the seasons and the weather (Book I); water, soil, seeding and sowing, manuring, harvesting cereals, winnowing grain, the preservation of cereals, pulses, and farm management (Book II); *works and days* (Book III); grape vine cultivation, including natural pesticides (Books IV–V); wine production and preservation, including special and aromatic wines, and also vinegar (Books VI–VIII); olive tree cultivation and oil (Book IX); fruit tree cultivation (Book X); trees, herbs, and flowers (Book XI); the orchard and its plants, including fertilizers and fertilizing methods, and pesticides (Book XII); beehives, bees, and honey (Book XV).

Actual Byzantine agricultural and horticultural practice is further attested by more recent textual documentation: the acts of foundation of monasteries, which specified to the very last detail all the components of monasteries, their equipment, and their function.[150] Extensive production in nurseries is attested in Egypt in antiquity. Plants were grown and traded in amphorae.

Agricultural activities were organized on a monthly and yearly basis. The monthly activities and the seasonality of produce dealt with in Book III of the *Geoponika*, are indirectly reflected by dietary calendars (below). Furthermore, the many astronomico-astrological texts and tables to be found in manuscripts[151] were predictive devices acting at two different, yet complementary levels.[152] At a first level, they predicted the yield of cultivation on the basis of the combination of at least three recurrent phenomena astronomical in nature: the circadian passing of the hours on a daily basis, the phases of recurrent astral phenomena such as lunar cycles on a monthly basis, and the seasons on a yearly basis. At this level, they acted more as a common-sense manual of

149 On gardening practices in Byzantium according to the *Geoponika*, see Rodgers, "Κηποποιία: Garden Making and Garden Culture in the *Geoponika*" to be complemented with Constantinides, "Byzantine Gardens and Horticulture in the Late Byzantine Period, 1204–1453: the Secular Sources."

150 On this, see Talbot, "Byzantine Monastic Horticulture: the Textual Evidence."

151 For a census of these manuscripts, and the publication of many of their texts, see *Corpus Codicum Astrologorum Graecorum*, published in 11 volumes between 1898 and 1951. Some texts have been occasionally published as, for example, Delatte, "Le traité des plantes planétaires d'un manuscrit de Léningrad," or, more recently, Ferraces Rodríguez, "Dos fragmentos inéditos de la antigua traducción latina del *De plantis duodecim signis et septem planetis subiectis* atribuido a Tésalo de Tralles."

152 On plant astronomy/astrology, see for instance Pfister, "Pflanzenaberglaube," or Pazzini, *Virtù delle erbe secondo i sette pianeti. L'erbario detto di Tolomeo e quelli di altri astrologi* (*Cod. Vat. 11423*), which analyses a broad range of texts.

agriculture, the predictions of which were valid through the years. At a second level, astronomico-astrological predictions acted on the basis of year-specific, not repeatable phenomena such as earth quakes, major atmospheric phenomena (torrential rains, or exceptional heat and consecutive drought, for example), all of which impacted upon agricultural production.

Some agricultural techniques deserve to be mentioned. Water management combined engineering in the Roman tradition with botanical techniques. It required cisterns to collect water (whatever its origin, spring or rain) and a grid of pipes (of clay, possibly underground) with valves, and/or channels (natural or made of stone, in the open air) with sluices to be manually handled, in which water ran by natural gravity. The use of some botanical species allowed for the optimization of watering: covering the ground between beds or rows of plants (the grape vine, for instance) with low herbaceous species that acted as a water saving technology. Not only did this ground-covering blanket prevent exposure to the sun, it also maintained a certain level of humidity, consequently reducing the need for water. Weeding was performed manually and also in a natural way by planting species that acted as weed killers thanks to the allelopathic mechanisms (*antipathy* between plants) known in antiquity. Conversely, plant *sympathy*, also known in antiquity, was used to improve the quality of some fruits, particularly the grape. Though for a long time this process was considered botanically unfounded, it is now being validated through genetic analysis.

Cultivated species are reflected in the range of foods consumed by Byzantine populations (below). They also included species for farm animals, small and not so small: poultry, ducks, geese, and pigeons, pigs, cows, goats and sheep. In normal conditions, species in cultivated fields were rotated, with one fallow year to restore the fertility of the land. Post-harvest fires and burning fields were used and duly mastered to provide soil with nutrients and to favour the growth of fire-resistant species, as well as creating the conditions necessary for some species to produce seeds. Fire barriers might have been created by planting rows of fire-resistant species such as laurel, carob, oak, or fruit trees.

Groves close to orchards or surrounding dwellings which acted as windscreens and/or fire-barriers, were not limited to fruit species, but might have included others, such as nut trees (pistachio and almond, for example) for human consumption, and Fabaceae species (carob, for instance) for feeding farm animals.

Beehives were placed close to relevant fields for two purposes: to provide a source of nectar for bees, and to take advantage of the bees' pollination activity.

## 8.2 *Alimentary Plants*

There are numerous sources dealing with the alimentary uses of plants. These include literary works such as, for example, Athenaeus, *Deipnosophistae*, medical manuals, dietetic treatises, and dietary calendars, in addition to dietary prescriptions in the acts of the foundation of monasteries (*Typika*).[153] Information on this matter was abundant and dated back to antiquity, with treatises that circulated in manuscripts in Byzantium, from the works on regimen in the *Hippocratic collection* to Dioscorides and Galen, including *De subtiliante diaeta* (*On thinning diet*) by the latter. Although some of the Byzantine texts have been published, so far many have not, and some have not even been inventoried. They still need to be located in manuscripts, exactly identified, adequately published, and carefully studied (including their authorship/attribution). Information gleaned from *Typika*, however useful it might appear, does not provide a full image of Byzantine food consumption, as nutrition in monastic communities was ruled by severe prescriptions that determined the range of foodstuffs. Some relevant information has been recently compiled, however, by Andrew Dalby, with texts, their translation into English, and recipes, together with a list of foodstuffs.[154]

Food procurement relied primarily on agriculture, and secondarily on harvesting in the wild. The gathering of nuts such as the chestnut, hazelnut, walnut, the pine nut, and the acorn, was common. Most of these were intended for domestic animal feeding, but shepherds and other seasonal workers, particularly during the summer, took to harvesting in the wild. This was a somewhat risky activity because it could lead to confusion and, consequently, poisoning. This is especially the case with edible bulbs that were easily confused with toxic ones, as for example the Autumn Crocus instead of Tassel Hyacinth.

According to a tradition going as far back as the Hippocratic treatises *De regimine* (*On Regimen*) and, most probably, much further, plants used for human consumption were classified into four major categories, usually presented according to the following sequence: cereals, pulses, vegetables, and fruits. As modern nutritional analysis has determined, cereals are a primary, though incomplete, source of protein, usefully complemented by pulses. Vegetables and fruits provide water, fibre, minerals, vitamins, and sugar.

153 All such acts have been published under the general title *Byzantine Monastic Foundation Documents. A Complete Translation of the Surviving Founders' Typika and Testaments*. Information about alimentation scattered in several such acts has been compiled and collected in the *Appendix B. The Regulation of Diet in the Byzantine Monastic Foundation Documents*, volume 5, pp. 1606–1716.

154 Both works were published in 2003: *Flavours of Byzantium*, and *Tastes of Byzantium. The Cuisine of a Legendary Empire*.

The range of food consumed in Byzantium was the traditional one by populations around the Mediterranean since antiquity.[155] Besides bread and other cereals such as barley, the diet comprised vegetables, with lettuce and different species of cabbage, carrots, beets, and leeks, in addition to onions and garlic, for instance, and legumes. Added to which would be several species of bean (except among local populations in southern Italy because of endemic favism), lentils, lupin, and chickpeas. Fruits were drawn from apples, pears, peaches and apricots, figs (fresh or dried), cherries, grape and pomegranate, in addition to berries from brambles. Nuts harvested in the wild or collected from cultivated trees completed this selection.

The choice of food was regulated by medical considerations, most probably amongst the wealthy,[156] while, for common people, it was regulated by traditional knowledge, encapsulated in dietetic calendars.[157] Such calendars formed a genre *sui generis* in Byzantine literature that flourished throughout the whole life of the empire. Some were astrological[158] others more botanical in nature.[159]

155 For a list of the plants for which Dioscorides, *De materia medica*, provides data about their nutritional value (or the lack thereof), see Touwaide, "Dietetics between Medicine and Culture in the First Century CE. A Survey from Dioscorides' *Materia Medica*." For the vegetables available to, and consumed by, Byzantines on the basis of the *Geoponika*, see Koder, *Gemüse in Byzanz: Die Versorgung Konstantinopels mit Frischgemüse im Lichte der Geoponika*. Also: Idem, "Fresh Vegetables for the Capital." For a focus on some species used as foodstuffs, see for example (alphabetical order of English name of plants): beet: Grepin, "The Words for 'Beet' in three interrelated Systems: Greco-Roman, Armenian and Arabic"; cucumber and melon: Paris/Daunay/Janick, "Occidental diffusion of cucumber, Cucumis sativus, 500 to 1300 CE. Two Routes to Europe," and Paris/Janick/Daunay, "Medieval herbal iconography and lexicography of Cucumis (cucumber and melon, Cucurbitaceae) in the Occident, 1300–1458"; liquorice: Putscher, *Das Süssholz und seine Geschichte*; rue: Pollio/De Natale/Appetiti/Aliotta/Touwaide, "Continuity and Change in the Mediterranean Medical Tradition: *Ruta* spp. (Rutaceae) in Hippocratic Medicine and Present Practices."

156 See, for example, the prescriptions in Oribasius, Books III and IV, in Reader's edition, with the English translation by Grant, *Dieting for an Emperor*.

157 On this genre of medical literature, see Jeanselme, "Les calendriers de régimes byzantins et la tradition hippocratique."

158 See for example the zodiac with vegetable produces according to the months in the sixth-century *Topographia Christiana* by Cosmas Indicopleustes, analyzed in Wingarten, "A Vegetable Zodiac from Late Antique Alexandria."

159 For some dietetic calendars, see, Hierophilus Sophistes (between the 7th and the 9th century), *De alimentis, quae singulis mensibus sumenda aut vitanda sunt* (*On the foodstuffs to be taken or avoided according to the months*), edited several times, first by Boissonade (with two editions), then by Ideler, and, subsequently, by Delatte. On it see Oeconomos, "Le calendrier de régime d'Hierophile d'après des manuscripts plus complets que le *Parisinus* 396." Also, and possibly of the same period, the anonymous calendar published

The traditional Mediterranean range of foodstuffs of vegetal origin was expanded in the Byzantine empire through contacts with neighbouring cultures and the immigration processes that punctuated Byzantine history. The most important of such contributions came from the Arabic world. Although it was not explicitly documented until the 11th century and the small compendium *De alimentorum facultatibus* (*On the properties of foodstuffs*) by Symeon Seth,[160] the introduction of previously unknown foodstuffs into Byzantium from the Arabic world had already started by the 10th century or even earlier when, in the 7th century, Greek and Arabic populations were in contact. Not all the botanical species introduced into the Byzantine empire through this process, whatever the time, were necessarily new. Some had already been present, but had been abandoned, particularly in the territories on the border of the Byzantine and Persian empires during the war of the 6th and 7th centuries, and similarly in Syria, during the wars against the Arabs.

In the history of ancient botany, including in Byzantium, spice constituted a field in its own right. Besides the culinary species typical of the Mediterranean region, spices included species imported from areas as far away as China and east tropical Africa. Several of them had been introduced early in the history of the Greek world along the Silk Roads. Though constantly present during the millennium of the Byzantine empire, the spice trade changed routes several times because of the geo-political conditions of the Near East. The two key regions were the Caucasus and Arabia, which were the endpoints of the Silk Roads. In between, the Arabic empire controlled the traffic westward from the East.

The range of the traded species sometimes fluctuated significantly, partly because of the accessibility of trade routes. Such fluctuations are reflected in the content of *De materia medica* in preserved manuscripts, fluctuations that can be accounted for by, among other factors, the availability of spices or their reintroduction. This reintroduction process is particularly clear after the diffusion of Arabo-Persian medicine, materia medica, and foodstuffs in the Byzantine world from the 10th century onward.[161]

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by Boissonade, and those, of unknown period, published by Ideler. Of the 12th century, Theodore Prodromos, *Calendarium dieteteticum*, edited by Ideler.

160 Symeon Seth, *De alimentorum facultatibus*, ed. Langkavel. In manuscripts, the text is sometimes attributed to Michael Psellus (1018–1070).

161 Spices are a rich field of investigation covering a broad range of aspects from drug trade to social, religious and cultural meaning(s). Publications on this topic are abundant. Suffice to mention here some such works published over the past 25 years that illustrate the richness and many facets of the field (chronological order of publication): Küster, *Wo der Pfeffer wächst. Ein Lexikon zur Kulturgeschichte der Gewürze* (a dictionary of the cultural values linked with spices); Ferrara Pignatelli, *Viaggio Nel Mondo Delle Essenze*;

Most of the oriental spices known and used in antiquity, which were still used in Byzantium, were described in Dioscorides, *De materia medica*. Both the text of *De materia medica* and the illustrations (when available) make it clear that neither antiquity nor Byzantium ever received and acclimated the spice-producing plants – however willing they might have been – or were successful in their attempt to cultivate them. As a result, both antiquity and Byzantium only had access to spices in the form of dried material, or possibly treated.

Preparations of plants and other foodstuffs for alimentary consumption differed greatly between groups within Byzantine society and according to periods and places.[162] Common people prepared food in a way that did not differ much from how it had been prepared in antiquity, boiling and grilling vegetables for immediate consumption, with oil and possibly also vinegar. Both oil and vinegar might have been aromatized with plants. Dishes were further spread with seeds such as cumin, poppy, or cornflower. Several species of vegetables were also marinated in brine or pickled for long-term preservation. Fruits were consumed fresh or dried. Monastic communities did much the same.

The upper class had their own ways. The culinary extravaganza of the Roman Empire, best reflected by the 4th century collection of recipes known as *Apicius*, does not seem to have been *à la mode* in Byzantium. Nevertheless, an abundance of food was typical, as was the luxurious context of food consumption. The food itself was dominated by a preference for seafood, particularly fish coming from the surrounding seas (whereas, in Rome, fish with far flung origins were very much sought after), together with the generous use of spices, most of which came from the East and were expensive. Abundance was reined in by the increasing medical control of food selection and consumption, and also by religious rules with multiple days of fasting.

Plants also provided the basis for many beverages, of which the first and most widely diffused was wine, with a great variety of types according to the vine and the location. The natural range of wine species was expanded by aromatizing wine with a great variety of species, as was also vinegar. The same aromatic plant species were used to prepare infusions that might also have

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Hamarneh, "Spices in Medieval Islam: a Perspective"; Dalby, *Dangerous Tastes.The Story of Spices*; and, more recently, Freeman, *Out of the East; Spices and the Medieval Imagination*.

162 The classical volume by André, *L'alimentation et la cuisine à Rome*, is still useful. Similarly, Schianca, *La cucina medievale. Lessico, storia, preparazioni* provides a wealth of information, particularly because it approached the Middle Ages as an interconnected world in which information (and culinary practices) circulated.

been consumed as medicines. Beer made from fermented cereals was available.

## 8.3 *Medicinal Plants*

A great variety of plants were used as ingredients for the preparation of medicines. The question of the cultivation of medicinal plants is one that has long intrigued scholars but has never been really tackled. However, it may be assumed that, since many of these plants were also consumed for nutritional purposes, they were grown together with alimentary plants. Furthermore, specialized cultivation may have existed. The recent discovery of what has been interpreted as a 6th-century pharmaceutical laboratory not far from Constantinople, includes traces of a garden containing species used for medicinal purposes. The plants in this garden are supposed to have provided the raw material for the remedies prepared in the laboratory (see pp. 396–397, and 400). Finally, it seems certain that medicinal species were grown in monastic gardens, the extension and production of which in Byzantium is not fully understood. Some information might be inferred by means of a comparison with Western monastic gardens of medicinal plants, which are better recorded.[163] In addition to cultivated species, many others would have been harvested in the wild.[164]

Most of the plants used for medicinal purposes were inventoried, described, and analyzed by Dioscorides in *De materia medica*. The subsequent encyclopaedias of the early Byzantine period (Oribasius in the 3rd century, Aetius in the 6th, and Paul of Aegina in the 7th) reproduced its information all or in part, and combined it in different ways with Galen's theoretical analysis. Original documentation for the subsequent periods until the 13th and 14th centuries is either scant or insufficiently researched. Western documents of the pre-salernitan period (until the 11th century) may compensate for these shortcomings, particularly because they have been more researched over the past decades. One such document is the recently rediscovered *Lorscher Arzneibuch* (dating back to *c.* 795), which is a medical manual not very different from later Byzantine ones.[165] The *Capitulare de Villis* (composed during the last quarter

163 On the St Gall plan for a monastery garden of medicinal plants to be possibly built, see essentially Horn/Born, *The Plan of St Gall. A Study of the Architecture and Economy of, and life in a Paradigmatic Carolingian Monastery*, vol. 1, pp. 302–313. On medieval gardens of medicinal plants more generally, see Keil, "*Hortus Sanitatis, Gart der Gesundheit, Gaerde der Sunthede*."

164 On this, see Scarborough, "Herbs of the Field and Herbs of the Garden in Byzantine Medicinal Pharmacy."

165 Its manuscript (a unicum) has been reproduced in a facsimile edition with a volume of commentary: *Das Lorscher Arzneibuch: Faksimile der Handschrift Msc. Med. 1 der Staatsbibliothek Bamberg*, edited by Gundolf Keil, 1989; the commentary contains a German

of the 8th century, but with its exact date still under discussion), provided a list of 95 herbs that had to be cultivated in the *villae* of the Holy Roman Empire,[166] and the *Hortulus* by Walahfrid Strabo (808–849) described the species cultivated in a garden of medicinal and alimentary plants.[167] An analysis of the plants in all Western gardens has demonstrated their continuity with the practices of antiquity, together with their innovations.[168]

The range of plants, vegetal material, and derivatives used medicinally varied over time, including because of contacts with different populations.[169] In the east, the Byzantine empire bordered with the Persian Empire until the 7th century. At almost the same time it came into contact with the Islamic Conquerors coming from the Arabian Peninsula. Furthermore, Byzantium attracted and assimilated several other populations, some coming from as far away as central Asia. There can be no doubt that contacts between, and interaction with, populations also resulted in the introduction of non-native medicinal species into the Byzantine practice. The major transformation resulting from such contacts was the introduction of Arabic medicine into the Byzantine world from the 10th century onwards. Such a process was all the more possible because the Arabic medicinal use of plants had been rationalized on the basis of Greek medicine, which had been introduced into the Arabic world from the late 8th century onwards through the translation of the fundamental Greek texts in the field. Although no exact list of species introduced into the Byzantine world by Arabic-speaking physicians is available, bilingual lexica of plant names (Arabic-Greek, with the Arabic terms written in the Greek alphabet)

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translation by Ulrich Stoll and Gundolf Keil in collaboration with Altabt Albert Ohlmeyer. For a critical edition of the text with a German translation and a study, see Ulrich Stoll, *Das "Lorscher Arzneibuch": ein medizinisches Kompendium des 8. Jahrhunderts* (*Codex Bambergensis medicinalis 1*). *Text, Übersetzung und Fachglossar*.

166 In its paragraph 70. For an edition, see Schmitz, *Die Kapitulariensammlung des Ansegis*.

167 The work has been repeatedly studied. See (in chronological order of publication): Sudhoff, *Des Walahfrid von der Reichenau Hortulus*; Payne/Blunt, *Walahfrid Strabo*; and Stoffler, *Der hortulus des Walahfrid Strabo*.

168 Opsomer, "The Medieval Garden and its Role in Medicine," pp. 106–13, with a list of the plants in Western medieval gardens and in the classical literature.

169 The work by Langkavel, *Botanik der spaeteren Griechen vom dritten bis dreizehnten Jahrhunderte*, though not an inventory of plants, can be consulted *in lieu*, even though it does not go beyond the 13th century. For the plants mentioned in the Western pre-salernitan texts as above, see Opsomer-Halleux, "The Medieval Garden and Its Role in Medicine," pp. 93–114, with a "Tentative List of Garden Plants" on pp. 106–12. Also, in a volume published on the occasion of the rediscovery of the Lorscher-Arzneibuch (*Das Lorscher Arzneibuch: Klostermedizin in der Karolingerzeit. Ausgewählte Texte und Beiträge*, 1989), there is on pp. 196–98 a list of the plants mentioned in the *Hortulus* together with their identification.

provide some indication about these species.[170] The same can be said about the introduction of Persian medicine into Byzantium at a later period.

## 8.4 *Bodily Hygiene, Cosmetics, and Perfumery*

Products for bodily hygiene, cosmetics, and perfumery were described in some detail in Dioscorides, *De materia medica*. Available written documentation was more abundant. However, judging from preserved manuscripts, no treatise specifically devoted to cosmetics written in Byzantium (if any) is known in the current state for research. Formulae for cosmetics and corporeal hygiene products made of plants and other natural substances did circulate in Byzantium. In *De compositione medicamentorum secundum locos* (*On the Composition of Medicines according to the Parts of the Body*) Galen cited some products which he attributed to Cleopatra, as did also Aetius in his *Libri medicinales*. Another relevant short manual containing formulae for cosmetics is that by the supposed Metrodora of uncertain date.[171] Compositions for cosmetics and bodily hygiene products are scattered through medical manuscripts, where they are difficult to locate because they are not well identified in currently available catalogues. Besides these and other authored formulae of dubious authenticity, anonymous ones can also be found in late Byzantine manuals of therapeutics. Knowledge of these formulae is still partial because of the absence of editions and, more especially, insufficient analysis and identification of the texts in the catalogues of manuscripts.

Whoever their author and whatever their nature and extension, compendia on cosmetics, bodily hygiene, and perfumery usually presented formulae according to the principle *a capite ad calcem* (from head to toe). They often contained sections on such topics such as hair tincture (usually decolouration to get a blonde colour, but also colouration in black), depilation, bodily hygiene, skin colour and imperfections, aesthetic artifices, and even nail care. In spite of their insufficient knowledge, screening of currently available editions and texts in manuscripts reveals that a broad range of plants was used, from laurel, for example, for black hair tincture, to resins aimed to glue eyebrows extensions, passing through the caustic sap of Euphorbiaceae for the removal of unwanted hair and dark spots on the skin.

Perfumes were mostly made of olive oil soaked with aromatic plant species. Soaking took place in two steps, with a first bath allegedly aimed to precipitate

170 Although some such lexica have been published among others by Delatte, *Anecdota Atheniensia et alia*, many of them still need to be researched. For a list, see Touwaide, “Lexica medico-botanica byzantina. Prolégomènes à une étude.”

171 On this supposed female physician, see Touwaide, “Metrodora.”

the fatty component of oil and, consequently, to make oil more receptive to the scent of the second bath of plants. The plant range included all scented species from roses to more exotic ones such as spikenard, for example, native to the Himalayas. Exotic substances such as cinnamon, which traded from Ceylon (now Sri Lanka), added a taste of oriental sensuality, and dying plants gave perfume a delicate colour such as yellow with saffron. Mosses and lichens were added into the mixtures as fixatives, according to an action not explicitly expressed in ancient materia medica and perfume literature, but confirmed by modern perfume-making. Perfumes also included more viscous substances such as myrrh or frankincense to provide consistency.

## 9 Going Beyond

As this presentation aims to make clear, botany in Byzantium was a multifaceted and complex field, deeply embedded in knowledge and life. It was by no means limited to the role to which thus far it has been reduced in traditional historiography, i.e. being simply the transmitter of the knowledge developed in antiquity to subsequent periods. Even if this were the case, Byzantium did not limit transmission through the centuries within the Greek-speaking world, but it transmitted inherited botanical knowledge to neighbouring worlds. Interestingly, having done so, Byzantium received its own knowledge back from these worlds, but in new, augmented and developed forms. As a result, botany in Byzantium, during one millennium, was created from materials of multiple origin, which was assembled, and expanded, into a unique and organically structured synthesis.

However new this image of Byzantine botany might be, it remains limited because much of the material cited here has so far never been thoroughly or even sufficiently investigated. Furthermore, the two major sources mostly used thus far for the study of Byzantine botany, Dioscorides and Galen's treatises, are in urgent need of new editions. In addition, many manuscripts still need to be systematically screened to find relevant texts. These texts should be published and possibly translated into a modern language to make them more widely accessible, and their data should not only be compiled into large collections to generate an image of Byzantine botany as complete as possible, but also finely analyzed by specialists of different disciplines from botany to the history of art, for example, working in collaboration in trans-disciplinary programmes.

It has to be expected that such renewed research on Byzantine botany will go beyond historical investigation and will document forgotten medicinal and

nutritional uses of plants, in addition to providing evidence for the accuracy and benefits of such uses for which the current reductive procedures of scientific validation cannot account, whereas persistence through the centuries of Byzantium and in different contiguous worlds suggests true value.

CHAPTER 10

# Medicine and Pharmacy

*Alain Touwaide*

Medicine in the Byzantine world is a vast, under-researched historical topic. Until recently, it was often considered as the product of the Dark Ages: at best an intermediary between Classical antiquity and the Renaissance that allowed Greek medicine to be transmitted to the West; at worst it was considered to be an impoverished derivative of Classical medicine resulting from obscurantism, superstition, and magic. Although research has recently renewed knowledge of medicine in Byzantium, work is still largely incomplete and leaves entire periods, areas, and topics unexplored.[1] The time has not yet come for a detailed, organically structured, and exhaustive presentation, so this chapter will survey the current knowledge about Byzantine medicine, with both results and lacunae. In so doing, it will identify topics that require further investigation, hopefully fostering new developments.

## 1 Framing Byzantine Medicine

In traditional historiography the history of ancient medicine is often limited to the production of knowledge (especially the works by the so-called *Founding Fathers* as Hippocrates (465–between 375 and 351 BCE), Dioscorides (1st cent. CE), and Galen (CE 129–after [?] 216), the activity of the different *Medical Schools* from Kos and Alexandria to the Methodists in Rome, large compilations, and encyclopedias such as Celsus' *De medicina* (*On medicine*) (1st cent. CE), in addition to specialized works as Soranus, *Gynaeciorum libri IV* (*On Gynecology*) (1st–2nd cent. CE). In this chapter, medicine will be taken in its broadest sense, to include not only the theories that contributed to the

1 For a thorough analysis of the research on the history of medieval medicine (not only Byzantium, but also the West and the Arabic World) up to 2015, see Touwaide, "Medicine." See also, more specifically about Western medieval medicine and complementarily, the two 2015 surveys by Wallis, "Medicine, Practical" and "Medicine, Theoretical." More generally, about Byzantine science, see Touwaide, "Byzantine Sciences" with an exchaustive study of the historiography, primary sources, methods, and available literature until 2010. The latter can be complemented by the following two essays: Griffin, "Historiography of Medieval Medicine," and Powrie, "Historiography of Medieval Science," both dated 2010.

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knowledge of the human body, health, illnesses, and the restoration of health, but also the individuals who generated such knowledge with their education, their professional and social status, the regulation of their profession, their instruments, the substances they used to restore health, together with the preparation of medicines, and the places where health professionals practiced their activity. The patients, their health, their susceptibility or, on the contrary, their immunity to or tolerance for disease, their illnesses-whether they were individual or collective-and their personal experience of health and disease will be considered together with their psychological impact, the reaction of patients to medicine, and their interaction with health professionals as far as currently available documentation makes it possible. Similarly, the places for learning, the professors and their teaching, the teaching programmes and manuals, as well as the intellectual context, and the major and minor schools of thought will be taken into account, together with the material component of knowledge—the history of the book, of libraries, of reading, and of information appropriation—inasmuch as they impacted upon knowledge and access to knowledge.

This expansion of the concept of medicine will be paralleled in the chronological and geographical frame of Byzantium. According to the chronology and geography of the political entity usually identified as Byzantium or the Byzantine empire, Byzantine history corresponds to the period from the transfer of the capital of the Eastern empire to Byzantium and the foundation of Constantinople by Constantine I in 330, to the capture of Constantinople on May 29, 1453 by the Ottoman troops. As for the geographical extension, the territory under Byzantine control varied over time, from the whole circum-mediterranean region at its maximal expansion, shrinking to Constantinople and its surroundings at its minimal extension. In the history of medicine such delimitations are too strict as they do not take into consideration the preceding period(s) and their contribution(s) to the making of Byzantine medicine, and the neighbouring worlds of Byzantium such as the West (which also needs to be better defined), the Persian world, the multiple ethnic, linguistic, cultural and religious populations around Byzantium in the East, Egypt and the southern communities, the Arabic world and, beyond it, India and even China, the Crusaders, and, later on, the many different groups of Turkish descent who entered the territory once controlled by Byzantium. Interaction of these and other populations with Byzantium was not limited to borrowing Greek medicine as per traditional historiography, but also included contributing to the medicine practiced within the Byzantine empire at different periods and in different ways according to the circumstances.

## 2 Sources and Methods

Whatever its form over time and the contributions of neighbouring worlds that it assimilated, medicine in Byzantium was rooted in the classical heritage. These origins left a strong imprint on medicine throughout the Byzantine period as medicine was a learned discipline the substance of which was expressed in—and transmitted through—written works of different forms: theoretical treatises and practical manuals (both sometimes illustrated), hospital case-books and formularies, or notebooks by individual physicians. This determined until very recently the approach to Byzantine medicine, which is fundamentally—if not exclusively—text-oriented according to a Western scholarly tradition dating back to the Renaissance. Until not so long ago, indeed, the agenda and methods of most inquiries into the history of Byzantine medicine were determined by its nature as a philological discipline aiming to provide accurate critical editions based on an exhaustive inventory and codicological/palaeographical description of manuscripts (including accurate identification of their texts), the reading and collation of the full text of the work(s) under consideration in all their extant manuscripts, and, whenever possible, on a solid *stemma codicum*. In the best cases, such critical editions included a translation into a modern language, a commentary (which is often literary in nature), and/or complete or selective word indices comprising, for example, terms of pathology or the names of the plants used for therapeutic purposes.

This focus on the written document has been all the more possible because, due to the upheavals of history, the material (archaeological) traces of Byzantine medicine have long been considered scant. The recent interest in the *realia* of ancient life—including medicine—has contributed to a shift in archaeological research, which has expanded its scope by assimilating the traces of daily life often neglected in the past. Macro-remains of plants, leftovers or traces of meals on dishes or cooking instruments, vases and containers once filled with products of any kind possibly used for health, and medical instruments and recipients of all sorts constitute new areas of archaeological research. More recently, a further and deeper shift has taken place (mostly thanks to DNA identification), making it possible to identify the genetic profile of populations, pathogens, or the state of health of populations including, for example, what is now identified as stress—alimentary deficiencies. This type of analysis is now also applied to invisible traces of plants found in a wide variety of containers or in the ground, thus pushing the limits of archaeology beyond the visible.

This expansion of the range of sources to be included in medico-historical inquiry and, consequently, of the methods to be used has provoked a transformation in the profile of the history of medicine—not only of Byzantine medicine. This development is still ongoing and is characterized by a significant contribution of laboratory analysis. The resulting multi-disciplinary approach is bringing to light data that were unthinkable a few years ago and have transformed the very concept of the medical history of the populations under consideration. Such new medical history goes way beyond the traditional textual approach; it might be defined as a shift from a two-dimensional to a three-dimensional image of the history of medicine. It is no longer about knowledge produced to analyze individuals, but knowledge directed to the individuals themselves who are the objects of this knowledge.

## 3 Historiography[2]

The source of the textual nature of the historiography of ancient medicine—be it Classical, Byzantine, Medieval or Arabic—can be identified in the Renaissance rejection of contemporary (actually medieval) medicine by such learned physician as Nicolao Leoniceno (1428–1524). The approach to, and the interpretation of, Byzantine medicine available in most scholarly literature derive from the methodological principles laid down at that time. With the exception of the edition of some Byzantine medical works,[3] Byzantine medicine was not taken into consideration by historiography until the early 18th century. Even then it was not treated in a monograph, but it was included in a project for a new history of medicine by Daniel Le Clerc (1652–1728).[4] The Englishman John Freind (1675–1728), who took up the history of medicine where Le Clerc left it (that is, at Galen), wrote the first history of medicine that included Byzantium.[5] The philologist of French origin Johannes Stephanus (or Jean Etienne) Bernard (1718–1793) followed with a critical edition of a fragment of the *Efodia* (*Travel manual*) that he mistakenly attributed to Synesios of

2 See Touwaide, "Medicine," Griffin, "Historiography of Medieval Medicine," and Powrie, "Historiography of Medieval Science."

3 Notably the Greek version of Aetios of Amida (6th century) in 1534 by the Aldine Press and of Alexander of Tralles (525–605 CE) in 1548 by Estienne, the Latin translation of Nicholas Myrepsos (floruit *c.* 1241) in 1541 by Weissenhorn and in 1549 by Oporinus, and the Latin versions of Oribasios (*c.* 325–after 395/6), Aetius, Alexander of Tralles, Paul of Aegina (7th cent.), John Zacharias Aktouarios (*c.* 1275–after 1328), and Nicholas Myrepsos in the *Medicae artis principes* of Henri Estienne published in 1567.

4 See Le Clerc, *Histoire de la médecine*.

5 See Freind, *The history of physick*.

Cyrene (*c.* 370–*c.* 413 CE),[6] and, fifty years later, with the edition (still in use) of the *Epitome de curatione morborum* (*Therapeutic manual*) by the 10th-century Theophanes Nonnos (whose exact identity [Chrysobalantes] was established only thirty years ago).[7] Another scholar interested in Byzantine medicine—actually in the Alexandrian commentators and possibly also in Oribasius—was the German physician and oriental philologist Friderich R. Dietz (1805–1836) of Königsberg (*Regiomontanus Prussorum*). Significantly enough, in order to prepare his critical editions, Dietz did not limit his work to consulting locally available manuscripts as did most of his predecessors, but he travelled through Germany, Italy (including the Vatican), Spain, France, and Britain, searching for codices containing the texts in which he was interested.

The search for manuscripts was not systematically pursued until the French historian of medicine Charles Daremberg (1817–1872), who travelled extensively throughout Europe. He announced a *Collection des médecins grecs* (which was not limited to Classical antiquity but included the early Byzantine period),[8] of which he published only the part devoted to Oribasius.[9] Daremberg's model was later followed by the Greek ophthalmologist established in Paris, Georges A. Costomiris (1847–1900), who expanded Daremberg's work in direction of Byzantium.[10] Almost at the same time the French physician and historian of medicine Auguste Corlieu (1825–1907) offered a general presentation of Byzantine medicine that might be defined as a portrait gallery.[11] It was shortly followed by two more specific treatments of the history of Byzantine medicine: a short one by Karl Krumbacher (1856–1909), from the rising school of Byzantine studies in Munich, in his monumental *Geschichte der byzantinischen Literatur*,[12] and another, more detailed, by the historian of medicine Iwan Bloch (1872–1922) in the general *Geschichte der Medizin* edited by the historians of medicine Max Neuburger (1868–1955) and Julius Pagel (1851–1912).[13] Both based their work on a direct contact with the sources, the data from which they presented in a descriptive, linear way. It should be noted that, whereas Krumbacher started from Justinian's time, Bloch covered the whole Byzantine period, dividing it into two phases: the 3rd and 4th centuries (including what became

6 See Synesius, *De febribus*, ed. Bernard.

7 See Sonderkamp, "Theophanus Nonnus."

8 See Daremberg, *Bibliothèque des médecins grecs et latins*.

9 See Daremberg/Cats (eds.), *Oeuvres d'Oribase*.

10 Costomiris, "Études sur les écrits des médecins grecs," in five parts (1889, 1890, 1891, 1892, and 1897).

11 Corlieu, *Les médecins grecs*.

12 Krumbacher, *Geschichte der byzantinischen Literatur*, pp. 613–20.

13 Bloch, "Byzantinische Medizin."

identified more recently as *Late Antiquity*), and the subsequent period (comprising the whole period from Christianity to the Fall of Constantinople).

With the 20th century the entire historiography of ancient medicine was substantially transformed. The search for manuscripts became the primary objective, with a special—if not exclusive—focus on Classical medicine and its aftermath until the end of the Alexandrian School in the seventh century, overshadowing and almost eliminating Byzantium (with very few exceptions). This is best represented by the *Corpus Medicorum Graecorum* (*CMG*) launched in collaboration by the Prussian and Danish Academies, specifically the German historian of ancient philosophy Hermann Diels (1848–1922), and the Danish historian of ancient science Johan Ludwig Heiberg (1854–1928). In conformity with philological methods, the *CMG* opened with an inventory of the manuscripts containing the works to be edited, especially those by Hippocrates and Galen.[14] The manuscripts of the other physicians of antiquity were listed in a second volume the title of which is indicative: *Die übrigen Ärzte* (*The remaining phyiscians*).[15] Among these *remaining physicians* were some Byzantines, most of them dating back to the early Byzantine world until the capture of Alexandria by the Arabs in 641, even though some from the late Byzantine period were considered. Of the several editions published in the *CMG* during the 20th century some were of Byzantine physicians: Oribasius,[16] Aetius,[17] and Paul of Aegina,[18] followed more recently by John of Alexandria,[19] and Stephanus of Athens (or Alexandria)[20] (both 7th cent. CE).

Although Diels' inventory of manuscripts provided the material for a history of medical texts in Byzantium and, more specifically, for a history of medicine in Byzantium, it did not generate any such development. Manuscripts were employed in a very limited way, mostly aimed at identifying the ancestor(s) of the later tradition and reconstructing the original text of the works under study. The readers and users of the manuscripts, the interpretation(s) of the texts they were reading, the new developments and original works that these texts fostered, or any other aspect of the circulation of texts, and their possible link with the practice of medicine were not considered. Some original contributions to the history of Byzantine medicine were published, however, which

14 Diels, *Die Handschriften der antiken Ärzte, I*.

15 Diels, *Die Handschriften der antiken Ärzte, II*.

16 Oribasius, *Libri medicinales, Synopsis as Eutstahtium, Libri ad Eunapium*, ed. Raeder.

17 Aetius Amidenus, *Libri medicinales*, I–IV, and V–VIII, ed. Olivieri.

18 Paul of Aegina, *Epitome medicinae*, ed. Heiberg.

19 John of Alexandria, *Commentarium in Hippocratis Epidemiarum Librum VI*, ed. Duffy.

20 Stephen of Alexandria, *In Hippocratis Prognosticum commentaria III*, ed. Duffy, and *In Hippocratis Aphorismos commentaria*, ed. Westerink.

might have been seminal had they received the attention they deserved. This is the case, for example, of the several articles on Byzantine physicians and manuscripts by the Greek historian of medicine Aristoteles Kouzis (1872–1961), which included a pioneering study of Byzantine hospital formularies,[21] and also an essay on the exchanges between Byzantium, on the one hand, and the Persian and Arabic worlds, on the other.[22] The same is valid for the publications by the French physician and historian of medicine Edouard Jeanselme (1858–1935) on Byzantine diet calendars,[23] and hospitals.[24] A clinician who consulted Byzantine manuscripts, Jeanselme used information from hospital manuals to attempt a first reconstruction of the medical activity within hospitals. A similar case might be that of Loren C. MacKinney (1891–1963) who was interested in illustrations related to medicine in medieval manuscripts. Well before the recent increase in the interest in illustrations as a primary source for historical investigation, he collected photographs of relevant illustrations in medieval manuscripts,[25] and compiled an inventory of such illustrations that might be considered as a complement to Diels' catalogue.[26]

While the historiography of Byzantine medicine was going through these ups and downs, its equivalent in the West and the Arabic world was making a substantial contribution, including fundamental *strumenta studiorum*. In the United States, Lynn Thorndike (1882–1965) was interested in long-term phenomena and in massive collections of material from primary sources. As early as 1923 he started publishing a history of experimental science (magic and what was identified as *pseudo-science*) that covers the period from early Christianity to the end of the 17th century.[27] Together with Pearl Kibre he compiled a catalogue of *incipit* of scientific treatises that resulted from the systematic browsing of medieval manuscripts.[28] Kibre herself pursued this line of investigation by systematically tracing the manuscripts of Latin translations of Hippocratic works across different periods.[29]

21 Kousis, "Contribution à l'étude de la médecine des zénons."

22 Kousis, "Quelques considérations sur les traductions en grec des œuvres médicales Orientales."

23 Jeanselme, "Les calendriers de régime."

24 Jeanselme/Oeconomos, "Les œuvres d'assistance et les hôpitaux byzantins."

25 MacKinney's collection is now preserved at University of North Carolina (UNC) at Chapel Hill, NC, where it can be accessed for research.

26 MacKinney, *Medical Illustrations in Medieval Manuscripts*.

27 Thorndike, *History of Magic and Experimental Science*.

28 Thorndike/Kibre, *Catalogue of Incipits of Mediaeval Scientific Writings*.

29 Kibre, "Hippocrates Latinus" published in 8 parts, and, further on, as a monograph under the same title.

From this same period, the history of Arabic medicine developed dramatically, providing material that would have been useful for historians of Byzantine medicine. Although Diels' catalogue included references to manuscripts of the Syriac, Arabic and Hebrew translations of Greek texts, it did not do so systematically. In any case, it did not generate fresh work on that basis, even though Arabic medicine was generally approached by Western scholars as an epiphenomenon of its Greek source and could thus have contributed to the reconstruction of Greek and Byzantine medicine. Among the historians of Arabic medicine whose research would have contributed to shedding new light on Byzantine medicine (even though they advocated a status in its own right for Arabic medicine) one should mention the German ophthalmologist Max Meyerhof in Cairo (1875–1945), the Egyptian Dominican Georges Anawati based at the Institut Dominicain d'Études Orientales (IDEO) in Cairo, Bishr Fares in Egypt, Cesar Dubler, author with Elias Terés, of a voluminous study of the fortuna of Dioscorides' *De materia medica*, which included the first edition of one of its Arabic translations.[30] More recently, the German philologist Albert Dietrich devoted his activity to the Arabic treatises on materia medica (including their Greek sources) and their lexicology,[31] and Juan Vernet Ginés in Barcelona specialized on al-Andalus.[32] Two comprehensive catalogues of Arabic authors, texts and manuscripts comparable to Diels' were compiled in the late 20th century: one by Fuat Sezgin in Frankfurt,[33] and the other by Manfred Ullmann in Tübingen,[34] who also worked on Dioscorides' Arabic translation(s),[35] and compiled a dictionary of the Arabic terms generated from Greek during the translation period in the Eastern Arabic empire.[36]

## 4 Current State of Research

It is only recently that Byzantine medicine started receiving more attention. The Dumbarton Oaks Symposium organized in 1984 by the American historian

30 Dubler/Terés, *La 'Materia Medica' de Dioscórides*.

31 Dietrich, *Dioscorides Triumphans*; *Die Dioskurides-Erklärung des Ibn al-Baitar*; and *Die Ergänzungen Ibn Gulgul's zue Materia medica des Dioskurides*.

32 Of him, see, for example, *La cultura hispanoárabe en Oriente y Occidente*.

33 Sezgin, *Geschichte des arabischen Schrifttums*, vol. 3.

34 Ullmann, *Die Medizin in Islam*.

35 Ullmann, *Untersuchungen zur arabischen Überlieferung der Materia Medica des Dioskurides*.

36 Ullmann, *Wörterbuch zu den griechisch-arabischen Übersetzungen des 9. Jahrhunderts*. The dictionary includes (pp. 15–51) a long treatment on the Arabic translation of Galen, *De simplicium medicamentorum temperamentis ac facultatibus*.

of pharmacy, John Scarborough, might be seen as a turning point,[37] although it was not followed by any similar gathering that would have contributed to developing a community of historians of Byzantine medicine and to laying down the basis for an academic discipline in its own right. As was the case before the Symposium, fresh activity in the field was undertaken—and still is—by individuals often doing research in different areas, instead of pursuing it within the framework of a specific programme. Maybe the sole exception is the Department of History of Medicine at the Medical School of the National and Kapodistrian University of Athens, where Aristoteles Eftychiadis, for example, specialized in Byzantine medicine.[38] Other faculty members of the same department occasionally studied medico-historical questions including—or especially devoted to—Byzantine topics.[39] Among the individuals who researched the history of Byzantine medicine during the last quarter of the 20th century, though not doing it in the context of a structured and specific programme, one might mention the late codicologist and historian of Byzantine law Josef Sonderkamp (1953–1990)—who participated in the Dumbarton Oaks Symposium—,[40] the historian of Byzantine literature Armin Hohlweg at the Ludwig Maximilian Universität in Munich until 2001,[41] and the Byzantine historian Timothy Miller, author of a monograph discussed below on Byzantine hospitals.[42]

Current research takes place in various academic institutions worldwide—including some independent ones such as the *Institute for the Preservation of Medical Traditions*—, while publications are scattered through historical collections and journals, without any being specifically devoted to the history of Byzantine medicine. The exception is the series of monographs, *Medicine in the Medieval Mediterranean*, which focuses on the Byzantine world as defined as above and thus covers the Eastern Mediterranean during the time period of

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37 The proceedings of the Symposium were published in the series Dumbarton Oaks Papers: Scarborough (ed.), *Symposium on Byzantine Medicine*.

38 See, for example, Eutichiadis, *Ἡ ἄσκησις τῆς βυζαντινῆς ἰατρικῆς*, and *Εἰσαγώγη εἰς τὴν βυζαντινὴν ἰατρικήν*.

39 See for example Laskaratos, "Ophthalmology in Byzantium," Laskaratos/Marketos, "Opthalmological therapy," and Laskaratos/Marketos, "The fatal disease of the Byzantine Emperor Andronicus III."

40 See his work on Theophanes Nonnos/Chrysobalantes, whose exact identity he was able to discover (Sonderkamp, "Theophanus Nonnus") and his investigation of the manuscripts of his treatise (Sonderkamp, *Untersuchungen zur Überlieferung der Schriften des Theophanes Chrysobalantes*).

41 See, for example, Hohlweg, "John Actuarius."

42 Miller, "Byzantine Hospitals"; *The Birth of the Hospital* (with two editions, the second of which corrected and revised); and "The Sampson Hospital."

the Byzantine empire. With the ongoing expansion of the sources for Byzantine medicine and the new application of analytical methods to archaeological material alluded to above, publications on Byzantine medicine now appear in scientific journals without relation to Byzantine studies and not even to historical studies that might escape the attention of interested scholars. The section on the history of medicine in the analytical bibliography of the *Byzantinische Zeitschrift* compensates as much as possible for this dispersion and collects the data of as many relevant, but scattered, publications as possible, summarizing their content and contribution to the history of Byzantine medicine.[43]

In its most advanced development, the history of Byzantine medicine directly benefits from the development of image technology, particularly the digitization of manuscripts and the availability of their images in open access on the Internet.[44] Thanks to new technical developments the treatment of digital images has allowed to read the text of palimpsests, and even to detect the palimpsest nature of manuscripts not previously suspected to have been palimpsested. This brought to light, for example, the existence of 5th-century medico-botanical illustrations such as those of the famous early-6th-century codex identified as the *Vienna Dioscorides* among the codices of the collection at St. Catherine Monastery of Mount Sinai.[45] Most recently, a new *Census of Greek Medical Manuscripts* has been published,[46] which will lead to what can be called a *New Diels*, with a comprehensive inventory of the texts contained in known Greek medical manuscripts and, for each such text, the list and location of their copies.

## 5 The Making of Medical Knowledge

When Constantine I founded a new capital for the Eastern Roman empire, available medical literature was made of the treatises attributed to Hippocrates but produced between the 5th century BCE and the 2nd CE, which were not

43 History of medicine publications are listed in the section 11 of the bibliography (Fachwissenschaften), sub-section C (Medizin, Pharmazie). Of interest also, the sub-sections B (Naturwissenschaften [Zoologie, Botanik, Mineralogie, Alchemie]) and E (Agrarwissenschaft).

44 See the Websites of the British Library, the Bibliothèque nationale de France (Gallica), and the Biblioteca Medicea Laurenziana in Florence (Teca Digitale), for example.

45 On the Vienna Dioscorides, see below. The Sinai palimpsest is manuscript 8 in the New Finds, Arabic collection, which has not yet been published.

46 Touwaide, *A Census of Greek Medical Manuscripts*.

organized in a single coherent and organic collection, but were an amalgam in progress rather than the structured collection they later became. The vast *oeuvre* of Galen was not transmitted in a unitary corpus, but fragmented in multiple manuscripts, and complemented by several works by physicians in all fields of medicine and with all theoretical backgrounds, some of which were massive (this is the case, for example, of *De materia medica* [*On the natural substances for the preparation of medicines*] by Dioscorides [1st cent. AD]) and others of different size.[47] Furthermore, society—and, with it, medicine, science and culture—was facing an unprecedented challenge which had deep, long-ranging implications: the introduction and diffusion of a new religion that had been officially adopted by the civil authority.

Regarding medical literature, early Byzantine physicians have been traditionally accredited by historiography for the compilation of encyclopedias that summarized available literature, mostly that of Galen. This approach is supposed to account for the production of the all-encompassing works by Oribasius, Aetius, and Paul of Aegina.[48] However correct it might be from a factual viewpoint, such interpretation does not take into consideration the fact that the medical literature available at that time was not organized in a systematic way, but was made of monographic treatises on multiple components of medicine as it was then understood, including works complementary to one another, duplicates, or even conflicting approaches to some sectors of medicine. The task of the early Byzantine physicians was not so much to compile well-organized and all-encompassing encyclopedias with literary qualities (something that they did, in effect), but rather to create a coherent medical library that made it possible for physicians to easily access relevant information for both practical and educational purposes. This work went beyond a simple assemblage, as it required locating and selecting throughout the available literature, the most relevant information (scientifically up-to-date, safe, and efficacious) in each field of medicine, and also putting together elements of different origins and possibly making them compatible. At the same time it was necessary to eliminate redundancy or conflicting information, and to organize the resulting collection of data in a structured and coherent construction. Although such work is often considered scholarly in nature, it might have been accompanied by the personal evaluation of information through practice

47 On the transmission of the Galenic corpus in Byzantium, see several of the contributions to Bouras/Zipser, *Brill's Companion to the Reception of Galen*, particularly Degni, "Textual Transmission of Galen in Byzantium."

48 For such a traditional approach, see recently Bouras-Vallianatos, "Galen in Late Antique Medical Handbooks" where what is called "handbooks" is in effect the encyclopedias by Oribasius, Aetius, and Paul of Aegina.

in order to assess feasibility, safety, and efficacy as seems to be the case, for example, with Alexander of Tralles.[49]

The case of Dioscorides, *De materia medica*, provides a revealing example of such work. It was a massive collection of data (over 1,000 chapters, each of which dealt with one or more substances used as an ingredient for the production of medicines) that covered all three natural kingdoms (vegetal, animal, and mineral), together with manufactured products.[50] This mass of information was organized according to a classification principle alluded to, but not explicitly described by Dioscorides himself,[51] which has been identified by John Riddle as "chemical affinities,"[52] though it might rather be a *scala naturae*.[53] According to traditional historiography, this structure was not preserved as early as Galen: all the chapters of the work were reorganized alphabetically, on the basis of the name of the materia medica they are about. Later on, this full alphabetical version was excerpted to create what is usually identified as the *Herbal* of Dioscorides, resulting from a double selection: animal and mineral materia medica was eliminated, and the vegetal materia medica was reduced by almost half. In the manuscript considered until recently as the most ancient copy of this *Herbal* (the so-called *Dioscorides Vindobonensis* dated to *c.* 512 and preserved at the Österreichische Nationalbibliothek in Vienna as medicus graecus 1), the text contains polychrome representations of plants characterized by two different styles: some naturalistic, apparently made from the direct observation of nature, and some rather flat, possibly reproducing dry specimens.[54] No explanation has been offered to account for the creation of this *Herbal*. An examination of the plants and their therapeutic uses shows that the *Herbal* results from two different sets of plants—the naturalistic one and the two-dimensional one—, each of which offers the same range of therapeutic applications. Furthermore, a comparison of all the classical and late antique/early Byzantine works on materia medica in which substances are listed according to the alphabetic order of their names reveals that none of these works matches, suggesting that there was no full alphabetical reorganization of *De materia medica* at that time. It is more probable that early Byzantine

49 Alexander of Tralles, *Therapeutica*, ed. Puschmann.

50 Dioscorides, *De materia medica*, ed. Wellmann. English translation by Beck, *Pedanius Dioscorides Anazarbus De materia medica*.

51 See the *Praefatio*, 5, ed. Wellmann, *Pedanii Dioscuridis Anazarbei de materia medica*, vol. 1, p. 3, ll. 9–11.

52 Riddle, *Dioscorides on Pharmacy and Medicine*.

53 Touwaide, "La botanique entre science et culture au I$^{er}$ siècle de notre ère."

54 Of the abundant literature on this point, see for example the handy synthesis of Mazal, *Pflanzen, Wurzeln, Säfte, Samen. Antike Heilkunst in Miniaturen des Wiener Dioskurides*.

physicians took *De materia medica* as a source of data from which they selected substances of proven efficacy, which they then reorganized in a convenient way. Two such collections—one made of ca. 240 items (the plants with naturalistic representations in the Vienna manuscript) and the other made of ca. 160 plants (those with two-dimensional representations)—were made independently, and assembled together prior to the Vindobonensis manuscript. The resulting assemblage was reproduced with some accuracy, maintaining the difference in style between the two collections of plant representations as in the Vindobonensis. Later, this *Herbal* was used up to the 15th century probably because it constituted a convenient collection of data.

The creation of a complete reference library for physicians as explained above, took place throughout the empire during the period spanning 4th to 7th century, and coincided with the development of a corpus for teaching purposes. This seems to have originated in Alexandria, particularly during the 5th and 6th centuries.[55] Two different, yet complementary methods were used: selecting relevant texts, and commenting on such texts. Several Hippocratic treatises, as well as introductory works by Galen were selected. The Hippocratic *Aphorismi*, for example, were especially suited to teaching as they embrace all sectors of medicine and offer material for reflection. Besides this and other Hippocratic monographic treatises, several Galenic works (possibly 16) were appropriate.[56] Since they required differentiated levels of knowledge of medicine, they were ordered according to an articulated programme characterized by its gradual complexity, from the short introductory *De sectis ad eos qui introducuntur* (*On the Medical Sects for Beginners*), which summarizes the different theoretical orientations of the so-called *medical schools* of the Hellenistic and Roman periods, to the longer *De sanitate tuenda* (*On the Preservation of Health*), which required advanced knowledge of medicine as it brings together anatomy, physiology, pathology, prevention, therapeutics, dietetics, and physiotherapy. Typically enough, these treatises were grouped in coherent units corresponding to the study-years that formed the complete teaching programme currently identified as the *Alexandrian Canon*.[57] If it actually existed, such a programme is not known in Greek, but only through Arabic texts where it is attributed to Gessius of Petra (d. *c.* 520), an Anqilaus not well identified but

55 See Iskandar, "An Attempted Reconstruction."

56 On this question, see Pormann, "The Alexandrian Summary"; and Walbridge, *The Alexandrian Epitomes of Galen*, with the edition of the Arabic version of some of these texts. Also, and more recently, Garofalo, "Galen's Legacy in Alexandrian Texts Written in Greek, Latin, and Arabic."

57 On it, see Walbridge, *The Alexandrian Epitomes*, particularly pp. xix–lii of the Introduction.

who might correspond to such known physicians as Archelaus, Agnellus or Asclepius, together with a Ioannês identified as *Grammatikos* and usually identified as Ioannês called *Filoponos* (*c.* 490–after 567 or 574) or John of Alexandria. There is also an otherwise unidentified Marinos who could be Magnus of Nisibis (fl. *c.* 370) whose name would have been erroneously transformed, Palladios (6th cent., second half), possibly the author of commentaries on Hippocratic and Galenic treatises, Stephanos identified as from Athens or from Alexandria (7th cent.), and an otherwise unknown Theodosios.

Textual commentary was the second method used to create teaching material. Texts were divided into coherent units, and the wording of each unit was closely examined and made explicit. The general meaning of the textual units under discussion was explained, possibly also by comparing or contrasting it with other passages from the same or other works, and several such textual units were grouped in order to form a lecture.[58] This method of teaching, which might correspond to contemporary hypertext development, might have been favoured by the introduction of a new book technology, characterized by the transformation of the shape of the book (the codex instead of the roll), which was accompanied by the use of a new medium (parchment instead of papyrus). This transformation might have taken place during the time period spanning 4th to 6th centuries, if not earlier.

The texts and teaching methods that might have been typical of the school of Alexandria, seem to have circulated across the Mediterranean as they seem to appear in the Ravenna of the Exarchate (584–751), particularly with Agnellus (late 6th–early 7th cent.).[59]

While these developments were happening, medicine needed to rethink itself to become compatible with Christianity, recently adopted as the official religion of the Byzantine empire. This was all the more necessary because medicine was an expression (and possibly the most achieved) of a world identified as pagan from then onwards. Whereas this transformation of medicine has often been identified with the introduction of a new anthropology that was Christian in nature, it was much deeper and extended into scientific illustration. Images of Greek gods such as Asclepius, for example, with a medicinal plant (which was probably aimed to represent the discovery of the therapeutic use[s] of the plant) were semantically debased and consequently abandoned in Byzantium, whereas they survived in the West and appear in later Latin medical manuscripts.[60] Hippocratic medicine was fundamentally compatible

58 On scientific and medical teaching in Byzantium, see chapter 2 of this volume.

59 Agnellus, *De sectis*, ed. Westerink; *De Sectis*, ed. Palmieri; *De pulsibus ad tirones*, ed. Palmieri.

60 See, for example, Vienna, Österreichische Nationalbibliothek, latinus 93, fols. 5v–6r.

with Christianity thanks to the attention it devoted to patients in a way that recalled Christ's care for the sick and subsequent Christian altruism.[61] Nevertheless, since it was pagan, it was subsumed through the cult to the healing twins Kosmas and Damianos.[62] The two twin brothers who practiced medicine in Asia Minor without asking for remuneration—hence their qualification as *Anarguroi*—, were martyred during Diocletianus' persecution (303). They then operated *post mortem* therapeutic miracles. Therapies proceeded by incubation in their sanctuaries, just as in the Asklêpieia of antiquity. Like their pagan predecessor Asclepius, the *Anarguroi* appeared to their worshippers to whom they revealed the cure allowing them to recover their health, as Aelius Aristides (117/129–*c.*181) did earlier.[63] The medicines they prescribed exactly reproduced those of the Hippocratic physicians. This transformation of Hippocratic therapeutics through healing miracles was most powerfully substantiated when Justinian himself visited the sanctuary of the *Anarguroi* in Constantinople to be treated for a disease that secular medicine could not heal. When he was cured, he restored the damaged temple of Kosmas and Damianos. The state of the temple, which most probably resulted from deterioration over time and accounted for this necessary restoration, attests to the presence of the cult to the twins even before the 6th century.

The attention to the practical dimension of medicine among Christian communities, further illustrated by the creation of the hospital,[64] went together with the development of a new theoretical anthropology. The question was not so much the analysis of the body or the justification of disease—which was not attributed to sin and punishment as a traditional interpretation often claims[65]—, but rather the question of free will. If humans were created by God, it was necessary to explain if they could act freely, and, assuming that they could, in what way. After Gregory of Nyssa (between 335 and 340–after 394) and his *De hominis opificio* (*On the Creation of Man*),[66] Nemesius of Emesa (4th–5th cent.) analyzed the notion of movement and self-determination in

61 Temkin, *Hippocrates in a World of Pagans and Christians*.

62 Of the abundant bibliography on the two healing saints, see the handy synthesis by Julien/Lederman/Touwaide, *Cosma e Damiano*.

63 See Israelowich, *Society, Medicine, and Religion in the Sacred Tales of Aelius Aristides*.

64 The question of the birth of the hospital—attributed to the Arabic World in bibliography until not so long ago—has been hotly debated. See Miller, *The Birth of the Hospital*, and, more recently, Crislip, *From Monastery to Hospital*.

65 For an analysis of this whole question, see Larchet, *Théologie de la maladie*, and, more recently, Crislip, *Thorns in the Flesh*.

66 Until the new edition in preparation is not completed, see *Patrologia Graeca* 44, cols. 123–256.

his *De natura hominis* (*On the Nature of Man*), with a particular focus on soul, destiny, and Providence.[67] With this treatise, he opened a new line of investigation that was further illustrated by the otherwise unknown Meletios,[68] and was much referred to in medical manuscripts and, hence, possibly among physicians.

The iconoclast crisis (726–843), which played a fundamental role in the definition of Byzantine identity and culture, might have impacted science and medicine, if medicine had not contributed, at least in part, to its rising. The debate about the veneration of icons might not have been limited to religion, but might have included a practical component, as the veneration of such icons as those of Kosmas and Damianos was considered to be a source of healing.[69] The real question of the debate was the operative power attributed to images, irrespective of the object represented by the image. A right understanding of images also meant an exact definition of their role as a means of communication. The restoration of images in the 9th century implied a redefinition of their status in culture—including science—as inert objects deprived of operative power. This did not eliminate, however, their role as devices for magic and other operative applications processed outside the realm of what was officially allowed.

The end of the iconoclast crisis was followed by the diffusion of a new type of writing—minuscule. With the separation of words, contrary to majuscule and the *scriptio continua*, minuscule contributed to a renewed production of books and the development of libraries. The manuscript tradition of many works—whether they were medical or not—shows that post-transliteration copies often descend from a unique transliteration, possibly hinting at a coordinated enterprise of transliteration aimed at avoiding duplication. Be that as it may, new copies of medical texts were produced, some lavishly illustrated, possibly under the patronage of the imperial court, particularly Constantine VII Porphyrogennetos (reign. 945–959). At that time, Constantinople had become the major cultural centre of the empire, especially after the conquest of Alexandria by the Arabs (641 CE) and the emigration of the scholars of the school to the capital.

67 Nemesius, *De natura hominis*, ed. Morani. English translation: Sharples/van der Eijk, *Nemesius, On the Nature of Man*.

68 The period of Meletios has been differently estimated (between the 7th and the early 13th century). See Talbot, *Meletios the Monk*. For his work, see Meletius, *De natura hominis*, ed. Cramer.

69 On this point, see in the same sense and for example Tomeković, “Maladie et guérison dans la peinture murale byzantine,” pp. 116–18.

The epoch of the affirmation of Constantinople, its books and its scientific production are characterized by the first signs of exchanges between Byzantium and the Arabic world, both in the East and the West.[70] After the Arab world emerged in the East as a political entity controlling a vast territory, it developed a scientific culture, starting with the absorption of contemporary science through translation. This process was not limited to Greek science, but also included Persian and Indian science, and possibly also Chinese. Regarding Greek science, the neighbouring cultures of Byzantium, particularly the Syriacs located at the junction of the empires—first Byzantium and Persia and, after the fall of the Persian world, the Byzantine and Arabic Empires—played a fundamental role as transmitters.[71] In the Arabic world, this process rapidly moved from the assimilation to the production of a new science with ensuing written production. The circulation of information reversed, going from Baghdad to Constantinople, instead of the other-way-round. A letter addressed to a Byzantine Emperor Romanos defined as Porphyrogennetos (Romanos II [?] [reign. 959–963]) accompanied the gift of a materia medica from Africa. According to the letter, this was a second embassy, which followed a first one by the father of the bearer of the letter.[72]

This kind of diplomatic exchange was not exceptional. It also took place between Constantinople and the Western Arabic world, that is, Andalusia. According to the well-known account by the Arabic historian of medicine ibn Juljul (*c.* 944–*c.* 994), a Byzantine Emperor identified as Romanos (not certainly Romanos II [reign. 959–963] because of chronological inconsistencies in the account) sent an illustrated copy of Dioscorides, *De materia medica* in Greek to

70 For an exhaustive analysis of this process across the Mediterranean (including Byzantium, the West, and the Arabic World), see Touwaide, "Transfer of Knowledge," with the methods, the primary sources, and the available literature as of 2010.

71 On the Syriacs, in general, see the recent volume by King (ed.), *The Syriac World*. On their role as transmitters, see, for example, the classical presentation of Hugonnard Roche, "Les traductions du Grec au Syriaque"; more recently, Le Coz, *Les médecins nestoriens au moyen âge*; Muraviev, "La médecine thérapeutique en syriaque"; Bhayro and Hawley, "La littérature botanique et pharmaceutique en langue syriaque," and Rudolf, *Syrische Astrologie und das syrische Medizinbuch*, particularly pp. 34–66, in addition to Montgomery, *Science in Translation*. The ongoing deciphering of what is called *the Syriac Galen palimpsest* (containing fragments of Galen, *De simplicium medicamentorum temperamentis ac facultatibus* [*On the mixtures and properties of simple medicines*]) will bring new information on this topic.

72 This letter is preserved in manuscript Oxford, Bodleian Library, Baroccianus 150, fols. 17v–18r. See Touwaide, *Medicinalia Arabo-Byzantina*, pp. 96–97. It has been further edited by Magdalino, "Pharmaceutical Diplomacy: A New Document on Fatimid-Byzantine Gift Exchange."

the court of Cordoba where the Arabic translation made in Baghdad in the 9th century was available.[73] As no local scientist could read Greek, the ambassador was sent back with a request for a scholar who would have help the physicians at the court in the understanding and interpretation of the Greek text. This is how a Greek monk named Nikolaos arrived at Cordoba where he collaborated with local physicians to improve the available translation, not, as historical studies have often suggested, to produce a new translation.

The circulation of information across the Mediterranean was accompanied by the introduction of non-native species of plants used for medicinal purposes—a common practice in the 11th century. Oriental species mentioned by Dioscorides and further abandoned in the copies of *De materia medica* made in the previous centuries, were reintroduced in the manuscripts of the work in Constantinople as early as the mid-11th century as the copy preserved at Mount Athos dating back to this period indicates.[74] In the Athonite codex, the representations of one of these plants re-introduced into Byzantine therapeutic practice closely correspond to that in an Arabic manuscript, something suggesting not only that Arabic manuscripts might have been present in Constantinople, but also that the plants introduced in that way were not necessarily living individuals, but drugs obtained from living individuals and processed in a dry form. This introduction of information related to materia medica typical of the regions under the control of the Arabic empire was further developed by Symeon Seth (11th cent.) who compiled a short *De alimentorum facultatibus* (*On Foodstuff Properties*) describing several substances coming from the East including such a distillate as camphor.[75]

At that time, the Mediterranean seemed to be widely open to exchanges between the different communities that inhabited it. Greek culture was going through a period of revival in Southern Italy. Salerno bishop Alfano (1015/20–1085) travelled to Constantinople from where he brought back Nemesius, *De natura hominis* (*On the Nature of Man*), which he translated into Latin.[76] This renewed interest in Greek science was further illustrated—though in an indirect way—by Constantine, known as the African (d. before 1098/99), who sought to reintroduce Greek medicine into the Latin world by translating into

73 On this well-known episode, see Vernet, *Ce que la culture doit aux Arabes d'Espagne*, pp. 81–85.

74 This is manuscript Ω 75 from the collection of the Great Lavra Monastery at Mount Athos. On it, see Christodoulos, "῾Ο Ἀθωνικὸς κώδ. Ω 75 τοῦ Διοσκορίδη." On this trade, see Durak, "Dioscorides and Beyond. Imported Medicinal Plants in the Byzantine Empire."

75 Symeon Seth, *De alimentorum facultatibus*, ed. Langkavel.

76 See Wicher, "Nemesius Emesenus," pp. 46–50.

Latin Arabic medical treatises that derived from Greek. In the following century, the Pisan judge Burgundio (*c.* 1100–1193) following in the footsteps of Alfano, translated Nemesius and several Galenic treatises in addition to other scientific works.[77]

Sicily also was particularly active. It was probably there that the *Zād al musāfir* (*Provisions for the Traveller*) by ibn al-Jazzār (898–980) from Al-Qairwan was translated from Arabic into Greek.[78] This version, currently known as the *Efodia* (*Travel manual*), is attributed to different translators in the manuscripts, one of whom is an otherwise unknown figure called Kônstantinos. Since the *Zād al musāfir* was also translated from Arabic into Latin by Constantine the African under the title *Viaticum peregrinantium* (*Medical Manual for the Travellers*), Constantine has often been considered as the author of the Greek version.[79] A closer analysis, however, suggests something different. Whereas the most ancient manuscript of the *Efodia* dates back to the 12th century,[80] and is partly the work of the scribe of the famous *Skylitzes of Madrid* acting in a high-level milieu,[81] it is by no means sure that the translation of the *Zād al musāfir* into Greek was made at that time and in that context. The text contains several layers of interpretation of terms originally not translated into Greek, but simply transliterated from Arabic into Greek. This suggests that a first translation might have been made by Greek and Arabic speaking physicians working in collaboration, unless it was made using a *lingua franca* made of Arabized Greek; also this first-hand translation was further annotated and revised by its readers and users (and even by several generations of readers and users), resulting in the multi-layered text that we know. This version generated among practitioners circulated in Sicilian society in a next phase, from the practice of medicine to scholarship, and it might have reached the high-level scriptorium where the *Skylitzes codex* was produced.

This possible bottom-up movement from practitioners to scholars and libraries (which is the opposite of the top-down scheme often accepted in historiography) was accompanied, in the case of the *Efodia* at least, by a movement of diffusion from the periphery to the centre—that is, from Sicily to Constantinople—, which differs from the centrifugal movement of cultural diffusion

77 Besides Wicher, "Nemesius Emesenus," pp. 50–54, see Durling, *Galenus Latinus I*, and *Galenus Latinus II*.

78 See, for example, Touwaide, "Medicina Bizantina e Araba alla Corte di Palermo."

79 Partial edition of the text, and attribution, in Bernard (ed.), *Synesius de febribus*.

80 Manuscript Vat. gr. 300.

81 For this identification, see Wilson, "The Madrid Skylitzes." The so-called *Madrid Skylitzes manuscript* is Madrid, Biblioteca nacional, Vitr. 26–2.

often considered to have taken place from the capital (Constantinople) to the periphery of the empire (usually the provinces or regions at the edge of the empire). Although another translation of the *Zād al musāfir* into Greek might have been made in Constantinople, it remains that the text of the *Vaticanus* seems to have been known in the capital.

The Fourth Crusade (1204–1261), which resulted in the occupation of Constantinople by Westerners, temporarily reduced activity in the Byzantine empire in exile in Nicaea, without stopping exchanges between communities, however, including in the field of medicine. With the capture of the imperial library by the Westerners, the *Dioscorides Vindobonensis* became available for new copies, one of which might have been made during the Latin occupation of Constantinople for an unknown physician and reached the West.[82] However reduced it might have been, activity at Nicaea was not interrupted. Nikephoros Blemmydes (1197–*c.* 1269) wrote several medical works,[83] including a verse treatise on urine perhaps intended for recitation in the way of a cantilena.[84] Possibly because of the occupation of the capital, scientists might have also emigrated to the islands as a later manuscript of Dioscorides (with notes related to Cyprus) might suggest.[85]

After the re-conquest of Constantinople by the Byzantines in 1261, medicine in the capital of the empire was more "internationalized" than in previous times. This might result from the almost simultaneous capture of Baghdad by the Mongols in 1258 and the collapse of the Arabic empire, which not only opened to Byzantines the way to the East, but also provided an opportunity to the Arabic scientists who fled the ex-capital of the empire. In Byzantium, society needed indeed to be rebuilt and reorganized, including medicine and the establishment of sanitary services. In the Eastern Mediterranean Arabic medicine was then the most advanced, and its introduction into the Byzantine world was beneficial to both parties: it offered opportunity for employment to exiled Arabic scientists, and it allowed Byzantines to rapidly recreate a medicine based on cutting-edge science.

Renewed activity in Constantinople benefitted from a further transformation in book technology, particularly the widespread use of paper as a medium. Scribes at that time returned to copies in majuscule (which dated as far back as

82 Touwaide, "Latin Crusaders, Byzantine Herbals."

83 See Kousis, "Les Oeuvres médicales de Nicéphore Blémmydes selon les manuscrits existants."

84 The text of his *De urinis* is edited in Ideler, *Physici et medici graeci minores*, vol, 2, pp. 318–22, under Psellus' name. For its interpretation as a work to be recited, see Diamantopoulos, *Musical Uroscopy*.

85 See Touwaide, *Les deux traités*, vol. 1, pp. 31–38.

the 9th century at the most) and transliterated them again into minuscule. This operation had a double, possibly contradictory effect: whereas it allowed the elimination of mistakes unavoidably generated by handwritten reproduction from one copy to another, it also led to the abandonment of the possible advances and developments in information introduced into the texts between the 9th and the late 13th century on the basis of the clinical experience of practitioners.

Among the scientists of the first generation in post-crusade Constantinople, Nicholas qualified as Myrepsos, compiled the *Dynameron*,[86] a vast formulary of pharmaco-therapy detailing the preparation of hundreds of remedies according to their pharmaceutical forms. Maximos Planoudes (*c.* 1255–*c.* 1305), who was interested in Nicander's poems (below), has been credited for a long time with the translation from Latin into Greek of the lost Aristotelian treatise *De plantis* (*On Plants*),[87] which was known then through the Latin translation of the Arabic version made by Alfred of Sareshal (12th/13th cent.). Fresh research has demonstrated, however, that the author of this version was Manuel Holobolos (*c.* 1245–between 1310 and 1314).[88]

Besides Byzantine scientists as those mentioned above, there were also Western scholars in the Byzantine empire, the most famous of whom might have been the Belgian Dominican, Wilhelm of Moerbeke (between 1215 and 1235–before 1286). Moerbeke had access to manuscripts copied by an otherwise unknown Iôannikios. These manuscripts offer accurate versions of the texts they contain, suggesting that Iôannikios used models dating far back in time, which had not been exposed to the transformations usually introduced into works through the centuries. Because of this, he was supposed to have been active in Southern Italy, possibly among the Hellenic minorities who preserved the legacy of the past more accurately than the inhabitants of the Byzantine empire. There were, however, elements in Iôannikios' production that hinted at a possible location in Constantinople. Recent research has revealed that Iôannikios was active in Constantinople under Manuel I Komnenos (reign. 1143–1180).[89] There, he copied manuscripts of Galen, Aetios, and Paul of

86 The Greek text of his work has been critically edited in a PhD thesis by Valiakos, *Η συμβολή του Νικολάου Μυρεψού*. The thesis is now available for free on the Propylaeum platform at the following address: <https://books.ub.uni-heidelberg.de/propylaeum/catalog/book/455>. For a first study, see Valiakos et al., "Ethnopharmacological approach to the herbal medicines" with two installments.

87 Hemmerdinger, "Le *De plantis* de Nicolas de Damas à Planude."

88 Fisher, "Manuel Holobolos, Alfred of Sareshel, and the Greek Translator of Ps.-Aristotle's *De Plantis*."

89 Iôannikios' production was studied in the following publications by Wilson, "A Mysterious Byzantine Scriptorium," "New Light on Burgundio of Pisa," and "Ioannikios and Burgundio"; and Vuillemin-Diem/Rashed, "Burgundio de Pise et ses manuscripts

Aegina, as did also the Pisan judge Burgundio of Pisa already mentioned, who translated some Galenic treatises into Latin.

With the second generation of post-crusade scientists, interest in, and ways of accessing, eastern medicine was transformed. Whereas the Greek medical texts produced thus far that mentioned oriental materia medica were mostly based on medicine in Arabic, those from the end of the 13th century and into the first decades of the 14th onwards include information originally in Persian. This material was not introduced into the Byzantine world by Persian, Persian-speaking, or Arabic scientists who emigrated from their native region to the empire—even though it might have been the case—, but by Greek scientists who travelled to the East to learn about local science, and brought back to Byzantium the data collected during their expeditions. Gregory Chioniades (between 1240 and 1250–*c.* 1320) originally went to *Persia* (that is, northern Iran) to study astronomy.[90] Besides astronomical texts, he also brought formulae for antidotes, and translated all this wealth of information into Greek.[91] His translations were characterized by multiple terms that were not translated, but simply transliterated from their original alphabet into the Greek one.

In Constantinople, John Zacharias Aktouarios (*c.* 1275–after 1328) compiled several medical treatises, including an encyclopedia in the manner of the physicians of the early Byzantine centuries, which collected contemporary knowledge and organized it in a systematic way such as *De Methodo Medendi* (*Method of Medicine*).[92] At around the same time, the Italian physician and philosopher known as Pietro of Abano (*c.* 1250–1315 or 1316) travelled to Constantinople and acquired texts by Galen and Dioscorides that he further translated into Latin.[93] He knew two different versions of *De materia medica*, which he compared when he commented on the work in his teaching at the university of Padua.[94] In the West, he was followed by Niccolò da Reggio (*c.* 1280–*c.* 1350) working at the Anjou court of Naples, who completed the work of translating Galen's vast production into Latin.[95]

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d'Aristote." For the location of Ioannikios in Constantinople as above, see Nesseris, *Η Παιδεία στην Κωνσταντινούπολη κατά τον 12ο αιώνα*, vol. 1, pp. 139–57. More recently, see Rodríguez Suarez, "From Greek into Latin," pp. 106–07.

90 Pingree, "Gregory Chioniades and Palaeologan Astronomy."

91 Touwaide, *Medicinalia Arabo-Byzantina*, p. 80.

92 The work contains 6 books, of which only the first two have been edited in Ideler, *Physici et medici graeci minores*, vol. 2, pp. 353–463.

93 For his translations of Galen, see d'Alverny, "Pietro d'Abano traducteur de Galien," and, more recently, Fortuna, "Pietro d'Abano e le traduzioni latine di Galeno."

94 Touwaide, "Pietro d'Abano sui veleni."

95 On him, see principally Weiss, "The Translators from the Greek of the Angevin Court of Naples"; McVaugh, "Niccolò da Reggio's Translations of Galen," and, more recently, Touwaide, "Niccolò da Reggio."

The generation active toward mid-14th century fully assimilated oriental medicine. Manuscripts of that time are full of texts of different length, the titles of which suggest that they came from populations identified as *Saracens*, *Persians* or *Indians*.[96] Multiple texts are anonymous as a brief tract on pulses translated from Syriac (*De pulsibus ex Syriaco* [*On Pulse* [*translated*] *from Syriac*]) and numerous formularies for antidotes identified as coming from Persia (*De antidotis ex Persia* [*On Antidotes* [*brought*] *from Persia*]). Others are presented as translations of authored treatises. Two of them, on sphygmology and urological diagnosis (*De pulsibus* [*On Pulses*] and *De urinis* [*On Urines*], respectively), are attributed to ibn Sina (980–1037),[97] better known in Byzantium and the West as Avicenna. Another, on cathartic medicines (*De purgantibus* [*On Purgative Medicines*]), is ascribed to John of Damascus (*c.* 675–749), whereas it was most probably by Yuhanna ibn Masawayh (777–857), identified as Mesue in the West.[98] And yet another is the small tract on smallpox and measles (*De pestilentia* [*On Pestilence*]) by Rāzi (865–925),[99] known in the Latin Middle Ages as Rhazes, which was probably not translated by Symeon Seth in the 11th century as has been suggested.[100] The Greek translation of ibn Sina's *De urinis* (*On Urines*) is interesting as it was made at least twice, with one of them claiming that the other—which becomes *ipso facto* the first—was not satisfactory. The text was popular as it circulated in more versions than the supposed two translations.

Interest in therapeutics was high towards the mid-14th century. All the preserved copies of Dioscorides, *De materia medica*, of the previous centuries were collected in the same place; those which had been damaged because of the upheaval of history were restored; a new transliteration from majuscule into minuscule was made; and a critical edition of the text based on available versions was produced. Also, new copies of the manuscripts with representations of the plants were made.[101] It might be the case that the monk known as Neophytos Prodromenos, as he was active at the Prodromenos monastery in the Petra neighbourhood of Constantinople, was at the centre of this renewed interest in Dioscorides.

96 Touwaide, *Medicinalia Arabo-Byzantina*, pp. 72, 78–80, 87–90, 92–93.

97 For *De pulsibus*, see Touwaide, *Medicinalia Arabo-Byzantina*, pp. 71–72. For *De urinis*, see Lamagna, "La *recensio amplior* inedita del *De urinis* di Avicenna" and "La *recensio amplior* del *De urinis* di Avicenna," with a critical edition in Lamagna, *Giovanni Attuario, L'eccellente trattato sulle urine di Avicenna*.

98 On this text, see Touwaide, *Medicinalia Arabo-Byzantina*, pp. 81–82.

99 Razi, *De pestilentia*, ed. Kouzis.

100 Congourdeau, "Le traducteur grec du traité de Rhazès sur la variole."

101 Touwaide, "The Development of the Paleologan Renaissance."

The study of Dioscorides, *De materia medica*, seems to have been accompanied by the compilation of a significant number of bilingual lexica of plant names, which provided the Greek equivalent of the Arabic names of plants that appear in the therapeutic texts of that time.[102] The interest in Dioscorides might be attributed to a reaction against the orientalization of materia medica and therapeutics. But this might not have been the case. Instead, increased interest in Dioscorides, together with these multiple lexica, might have aimed at connecting the two medical cultures, making it possible to link Arabic and Persian plant names with their Greek equivalent and, through this, with the description of the plants in *De materia medica* and their representation in manuscripts.

Neophytos Prodromenos and the activity devoted to Dioscorides' work was not just textual, but was most probably aimed at medical teaching and practice. The Prodromenos Monastery—known as the Petra Monastery from the name of Constantinople neighbourhood in which it was located—was adjacent to the hospital known as the *Xenodocheion tou Krali* (Hospital of the King), that is, the hospital founded by Stefan Uroš II Milutin (reign. 1282–1321), sovereign of Serbia. The hospital also hosted a library (where many of the Dioscorides' copies of previous centuries were preserved, as well as several other medical and non-medical manuscripts), a scriptorium (where several of the texts translated from Arabic and Persian into Greek were reproduced), and a school where not only medicine, but also philosophy and logic were taught.[103]

The Serbian presence in Constantinople also led to medical exchanges between Constantinople and the Serbian world. The so-called *Chilandar Manuscript* of the 15th or 16th century[104] contains medical treatises and formulae for medicines that strongly resemble their Greek equivalents of that period.

This period of intense activity was followed by a sharp decline in the early 15th century in spite of the efforts of such an individual as John Chortasmenos (*c.* 1370–before 1439) who commissioned a restoration of the *Dioscorides Vindobonensis*, probably hoping it would be used for years to come. Demetrios Pepagomenos, active during the first half of the 15th century and in contact with Chortasmenos, wrote a small treatise on gout (*De podagra* [*On Gout*]),[105]

102 For a census of these lexica, see Touwaide, "*Lexica medico-botanica byzantina*," which includes references to their manuscripts and, when applicable, to the critical edition of their Greek text.

103 For a synthesis of these elements, see Touwaide, "Un recueil grec de pharmacologie du X^e^ siècle illustré au XIV^e^ siècle."

104 MS. 517 of the Chilandar Monastery at Mount Athos (Greece).

105 Demetrios Pepagomenos, *De podagra*, ed. Kouzis. He also wrote on veterinary medicine; see among others and recently Lazaris, "La production nouvelle en médecine vétérinaire." On him, more generally, see chapter 11 of this volume.

and also a short manual of medicine.[106] At this time new copies of earlier manuscripts were made, some of which reproduced—though inelegantly—the illustrations contained within these manuscripts.[107] In the very last years of the empire, John Argyropoulos (*c.* 1393/4 or [?] 1415–1487), who earned a medical degree from the university of Padua in a significant inversion of the exchange fluxus, later taught medicine at the *Xenodocheion tou Krali* (Hospital of the King), and educated the last generation of Byzantine physicians before leaving the capital after its capture and emigrating to Italy.[108]

## 6 Medical Demand and Offer

The practice of medicine in Byzantium is difficult to perceive, not only because of the paucity of relevant information—we should not forget that inventories of Greek medical manuscripts had not been systematically compiled until very recently—, but also, if not more significantly, because the state of health of populations cannot be assessed with precision, as can neither their pathologies nor, consequently, their epidemiology.

The presentation of medical activity in Byzantium below follows as much as possible the itinerary of the management of a medical condition, from illness to treatment, starting with the patient, his diseases and his perception of his medical condition, followed by the physicians and the place of health care, in addition to the analysis and treatment of the disease, including an evaluation of the efficacy of remedial therapy.[109]

### 6.1 *Prevention of Disease*

Special attention was devoted to health preservation and disease prevention through nutrition in the most authentic Hippocratic tradition best represented by the treatise *De regimine* (*On Regimen in Health*).[110] Attention to nutrition

106 Demetrios Pepagomenos, *Liber medicinalis*, ed. Capone Ciollaro.

107 This is the case, for example, of the codex of Bologna, Biblioteca Universitaria, 3632, which contains, among others, copies of the representations of plants that accompany the text of Dioscorides, *De materia medica*, in the Vienna Dioscorides.

108 Mondrain, "Jean Argyropoulos professeur à Constantinople" and also Touwaide, "The 'Letter … to a Cypriot Physician' attributed to Johannes Argyropoulos."

109 For a general presentation of the practice of medicine, see the syntheses by Eutichiadis, *Ἡ ἄσκησις τῆς βυζαντινῆς ἰατρικῆς ἐπιστήμης καὶ κοινωνικαὶ ἐφαρμογαι αὐτῆς κατὰ σχετικὰς διατάξεις*, and Eutichiadis, *Εισαγωγή εις την Βυζαντινήν θεραπευτικήν*.

110 Edition (with English translation) in Jones, *Hippocrates IV*, pp. 44–59.

accompanied the awareness of the dual nature of the substances absorbed as both nourishment and medicine.[111] Multiple treatises on the properties of foodstuffs can be found in manuscripts, sometimes together with calendars for a healthy regimen that detail the foodstuffs to be taken according to the seasons, the months, and possibly also the days of the month and the phases of the moon.[112] Contrary to a widely diffused opinion, such prescriptions—with the exception of references to the seasonality of food production which was common knowledge—are not necessarily the expression of astrological irrational beliefs, but might result, instead, from the empirical experience of the differentiated growing process of plants according to the astronomical calendar (for instance, the phases of the moon) and other natural phenomena.[113]

### 6.2 *Epidemiology: Identifying Ancient Diseases*

The question of the identification of ancient pathologies—going beyond macro-structural, traumatic or externally perceptible signs identified and analyzed by palaeo-pathologists[114]—has been debated, mostly in the last quarter of the 20th century. Some medical historians, physical anthropologists, and physicians interested in the history of medicine thought it was possible to equate ancient and modern pathogens, while others argued that the evolution of pathogens made research of this type impossible. The recent transformation of genetics and laboratory methods for ancient DNA identification (that is, aDNA) on the basis of skeletal remains have profoundly transformed this debate in spite of the extreme difficulty of the task because of the contamination of archaeological remains during excavations, the difficulty of extracting relevant material (often pulp from teeth), and also in-house contamination during the analytical process. In recent times this kind of research has successfully established, for example, that the strain of pathogen responsible for the

111 On this point, see Touwaide/Appetiti, "Food and medicines in the Mediterranean Tradition."

112 For example, Hierophilus, *De alimentis, quae singulis mensibus sumenda aut vitanda sunt* (*On the foodstuffs to be taken or avoided according to the months*), repeatedly edited, including by Ideler, *Physici et medici graeci minores*, vol. 1, pp. 409–17, and, more recently, by Delatte, *Anecdota Atheniensia*, pp. 455–66.

113 See also chapters 6 and 13 of this volume.

114 Work has been done on the identification of some diseases (case-studies). See, for example, Codellas, "The Case of Smallpox of Theodorus Prodromus"; Lascaratos/Marketos, "The cause of death of the Byzantine Emperor John I Tsimisces (969–976). Poisoning of typhoid fever?," or Lascaratos/Zis, "The Epilepsy of Emperor Michael IV, Paphlagon (1034–1041 CE)."

6th-century epidemic of plague corresponds to a present-day form.[115] Going back further in time, bio-molecular research applied to skeletal material has provided evidence of traces of malaria in a mid-fifth century cemetery north of Rome,[116] a discovery that provided some substance to the historiographical narrative of the impact of malaria on the declining history of Rome. On this basis, it has been even hypothesized that the disease might have saved Rome from being attacked by Attila (d. 453). Though the Hun and his troops went down through Italy, they suddenly, in a volte-face that has puzzled historians ever since, stopped in 452 without any apparent reason. It might have been awareness of the presence of malaria that convinced Attila to abandon his project to conquer Rome, as he would have lost many of his troops had he entered the malaria-devastated region surrounding the city.[117] Be that as it may, medical history can now approach ancient pathology with rather more plausibility on the basis of the evidence provided by the identification of pathogens. In so doing, medical history takes on a new dimension. On the basis of physical evidence it brings to light phenomena that cannot be known through any other source and contributes to explaining historical facts previously unexplained, and even inexplicable.

### 6.3 *Epidemiology: a Quantitative Essay*

In the current state of research, evidence of this type is still scattered, and does not allow for a reconstruction of the epidemiology of the populations under consideration, and even less a quantitative approach, differentiated through time, and evolutionary.

Textual data, particularly treatises on therapeutics, might provide some information. Assuming that there is a positive correlation between, on the one hand, the number of therapeutic agents available to treat a medical condition at any given time in a population (and also the number of the uses of such therapeutic agents) and, on the other hand, the frequency and virulence of such a condition among this population, it might be possible to quantify the presence of the illnesses affecting that population at a certain point in time or, at the very least, the illnesses for which some therapeutic agents were available (which excludes both benign [usually non treated] and incurable medical conditions). For such a projection to be possible, research requires general works on pharmaco-therapeutics that list, describe, and mention all the therapeutic applications of most, if not all the agents used within a certain population at a certain point in time to treat its medical conditions. Dioscorides, *De materia*

115 Sallares, "Ecology, Evolution, and Epidemiology of Plague."
116 Soren/Fenton/Birkby, "The Infant Cemetery at Poggio Gramignano."
117 Sallares, *Malaria and Rome*.

TABLE 10.1 Number of occurrences of the agents to treat medical conditions by major anatomical or physiological systems according to Dioscorides, *De materia medica*, 1st century CE including their percentage of the total number of therapeutic agents

| | **occ.** | **%** |
|---|---|---|
| skin, nails, mucous | 626 | 11.64 |
| gastro-intestinal system | 596 | 11.08 |
| toxicology | 481 | 8.94 |
| gynaecology, obstetrics | 377 | 7.01 |
| urinary tract | 348 | 6.47 |
| respiratory systems | 327 | 6.08 |
| eye, sight | 316 | 5.87 |
| bones, joints | 231 | 4.29 |
| wounds, ulcers | 223 | 4.14 |
| humours | 140 | 2.60 |
| inflammations | 138 | 2.56 |
| mouth, throat | 130 | 2.42 |
| ears, hearing | 120 | 2.23 |

*medica*, lends itself to such an approach, which yields Table 10.1, in which groups of medical conditions (defined by major anatomical or physiological systems on the basis of Dioscorides' information) are ranked according to the number of occurrences of the agents mentioned to treat the pathologies affecting each such system.[118]

If such approach is applied to the *Herbal* compiled on the basis of *De materia medica*, it yields similar data,[119] something suggesting that the selection of materia medica from which the *Herbal* resulted was not aleatory, but was most probably based on some sort of statistical approach to the epidemiology of the populations to be treated by using Dioscorides, *De materia medica*. It can be accepted, at the very least as an hypothesis, that the numbers in Table 10.1 reflect with some plausibility the state of epidemiology of the populations among whom *De materia medica* was used. Furthermore, since the work was used throughout the history of Byzantium, it might be postulated that the

118 On these data, see Touwaide, "Disease." The table that follows presents only the 13 pathologies with the highest number of occurrences and, consequently, the highest percentage.

119 For the resulting tables, see Touwaide, "Byzantine Hospital Manuals," pp. 169–72.

epidemiology it reflects corresponds to some degree to that of the Byzantine populations during the centuries of the empire. The epidemiology reflected by these numbers may be identified as the *coenopathosis* of Byzantine populations as the late Mirko Grmek (1924–2000) defined *coenopathosis*, that is, the set of all the pathologies that affected a population at a certain point in time.[120]

This epidemiology might have come under stress when new pathologies entered the Byzantine area. Actually, these were not new pathologies *stricto sensu*, but pathologies that were not those of the Byzantine world and were introduced from outside. Recent research has shown that traders and products along the Silk Roads, for example, acted as vehicles for the transmission of pathogens from China to the Mediterranean.[121] It might be the case that the introduction of new materia medica into the Byzantine world was linked to the appearance of these new pathologies. If so, treatments circulated together with the pathologies infecting the populations into which the pathologies were introduced. A sign of this might be, for instance, the translation from Arabic into Greek of Razi's treatise on measles and smallpox, which might have been necessary because of the introduction of this disease into the Byzantine empire.

Be that as it may, other works should be analyzed to complete the epidemiologic image tentatively reconstructed above, particularly works known to have been written during periods of stress such as the epidemics of plague or episodes of famine, all of which have been inventoried on the basis of available documentation.[122]

### 6.4 *Perception of Disease and Medicine by the Patients*

The perception of diseases by patients,[123] and the attitude(s) to suffering were transformed with Christianization,[124] and, consequently also, the relationship

120 For an explicit definition, see Grmek, *Les maladies à l'aube de la civilisation occidentale*, pp. 14–16; English translation: *Diseases in the Ancient Greek World*, pp. 2–4.

121 Yeh et al., "Early evidence for travel with infectious diseases along the Silk Road."

122 For the epidemics of plague, see for example Congourdeau, "La Peste noire à Constantinople de 1348 à 1466"; for famine, see Stathakopoulos, *Famine and Pestilence in the Late Roman and Early Byzantine Empire*.

123 For studies on the *histoire vécue* of illnesses and their individualized perception(s) and re-elaboration(s), see recently Timplalexi, *Medizinisches in der byzantinischen Epistolographie*, particularly pp. 149–64; Sopracasa, *Aspetti dell'immaginario bizantino: le fantasie e la verità nella malattia*, and *La percezione della malattia e della guarigione*.

124 A good example of this is Gregory Nazianzus, whose case has been studied, among others, by Milovanovič, "*Here I am a Breathing Corpse*: Did Gregory of Nazianzus Suffer from Leprosy?"

between patients and healers.[125] The impact of the approach to disease on pathogenesis was known. It was sharply illustrated, for instance, by Aelius Aristides, whose works—including the so-called *Sacred Discourses*—were read in Byzantium until at least the 12th/13th century.[126]

The cult of Asclepius was abandoned, but its rituals, particularly the *incubatio* process and the revelation of therapeutic methods through dreams, were transferred to the healing twins, Kosmas and Damianos.[127] This takeover deeply modified patients' behaviour in the management of medical conditions through the veneration of the saints and pilgrimages to their churches, which spread across the empire. Among the many healing saints, one could mention Thecla (1st cent. CE; feast: September, 23),[128] Panteleimon/Pantaleon (2nd/3rd cent. CE; feast July 27), Artemius (4th cent. CE; feast October 10),[129] or Kyros and John (before the 5th cent. CE; feast January 31).[130] This healing phenomenon soon extended to other holy figures, who became the sources of therapeutic miracles.[131] Therapeutic interventions as these became a source of inspiration for works of art on multiple media, with very different techniques, and in numerous forms, which was very popular in Byzantium and the medieval west.[132]

125 For an example of a study of the relationship between patients and physicians, see Israelowich, *Patients and Healers*.

126 On Aelius Aristides, see Israelowich, *Society, Medicine and Religion in the Sacred Tales of Aelius Aristides*. For the *Sacred Discourses* see the edition by Behr.

127 For their story and therapeutic miracles, see the edition of the Greek text by Deubner. French translation (with an introductory study) in Festugière, pp. 85–213.

128 For the Greek text of the miracles, see the edition of Dagron and more recently, the edition (with facing English translation) of Johnson. For a French translation (witn an introductory study), see Festugière, pp. 11–84. For a study, see Johnson, *The Life and Miracles of Thekla*.

129 For the therapeutic miracles performed by St. Artemius, see the edition of Crisafulli/Nesbitt.

130 Edition of the Greek text, with a study, by Fernandez Marcos. French translation of the Greek text (with an introductory study) by Festugière, pp. 217–56.

131 See, for example, Athanasios I, Patriarch of Constantinople, author of posthumous therapeutic miracles (edition of the Greek text by Talbot) and Gregory Palamas (edition of the Greek text with English translation in Talbot/Johnson, *Miracle Tales from Byzantium*).

132 For the miracles of Kosmas and Damianos, see the corpus collected by David-Danel, *Iconographie des Saints médecins Côme et Damien*; also Julien/Ledermann/Touwaide, *Cosma e Damiano*, where an ample collection of iconographic material is reproduced. More generally on this iconographic topic, see Jackson, *Marvellous to Behold*, for the medieval period, and Cardarelli/Fenelli, *Saints, Miracles and the Image*, for the continuity

## 6.5 *Physicians*

Medicine was most probably practiced in the first instance within households, particularly by the wise and experienced older women of the communities as is still nowadays the case in rural areas. This may have been less true, however, in the large metropoles of the Byzantine empire.

Learned physicians received a specific education in medical schools as, for example, in Alexandria (where their *curriculum studiorum* was methodically programmed[133]) and, later, in Constantinople where a medical school adjacent to the *Xenodocheion tou Krali* remained active until the end of the empire.[134]

Whereas some physicians might have been more interested, and possibly also particularly successful, in some specific medical activity (as Paul of Aegina, for example, in surgery) and have compiled specialized treatises on such topic, it is not clear whether there were or were not medical specialists in the sense that we understand them, with the possible exception of gynaecology and obstetrics (which, however, could have been the province of women in the households).

Judging from the early Byzantine all-encompassing medical synthesis of Oribasius, Aetius, and Paul of Aegina, and the manuscript tradition of their works throughout the Byzantine centuries, or later works such as that of Theophanes Nonnos/Chrysobalantes, for example, it is much more probable that physicians were what we call now *general practitioners*.

Whatever their competences, health professionals in Byzantium had a broad range of statuses and ranks in society, from court physicians to local practitioners hired by the civil authority, including itinerants healers, quacks, and others of real or dubious ability.[135]

No comprehensive prosopographical list of Byzantine physicians has been compiled thus far, except some prosopographical notes by the Greek historian of medicine Konstantinos Pournaropoulos (1909–1992).[136] However, a list of

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of this genre in the Renaissance. For an interpretation of healing miracles (including a comparativist aprroach), see Woodward, *The Book of Miracles*. For artistic representations of healing saints, see Damianos of Sinai, "The Medical Saints of the Orthodox Church in Byzantine Art."

133 See above, p. 366–67.

134 See above, p. 377 and 387–88.

135 For physicians hired by the civil authority (*archiatri*), for example, see Nutton, "Archiatri and the Medical Profession in Antiquity."

136 See Pournaropoulos, "Έλληνες ιατροί και σοφοί λόγιοι από το Βυζάντιον εις την Αναγέννησιν," and "Προσθήκαι εις τους μέχρι σήμερον γνωστούς Βυζαντινούς ιατρούς."

epigraphical sources for physicians in antiquity covers a time span extending up to the 5th century CE,[137] and general prosopographies from Late Antiquity to the late Byzantine empire contain multiple entries on physicians.[138] The critical editions of medical texts usually offer a biographical essay on the authors of the edited text.[139]

## 6.6 *The Medical Practice and Its Regulation*

Details on the practice of medicine are best known through the acts of foundation (*Typika*) of monasteries, from the *Pantokrator* (below) and its hospital to the most recent *Bebaia Elpis* and its infirmary.[140] All aspects of the profession were accurately described. At the *Pantokrator*, for example, four physicians (two of whom were surgeons) were in charge of receiving patients from outside in what can be defined as *ambulatory* or *outpatient care unit*. They were accompanied by two assistants and four auxiliaries. When necessary, these physicians contacted the chief physician of the wards, and the latter dispatched the physician most appropriate according to the case, to examine the patient and decide the treatment and possible measures to be taken. For the patients who necessitated a longer observation or treatment, the hospital had fifty beds divided into five wards. Each such ward was supervised by two physicians (one of whom was a chief physician), three assistants with two auxiliary assistants, and two orderlies. In the female ward, the two physicians were assisted by a female colleague. The two surgeons of the outpatient unit treated the female patients in case of open wounds. All physicians were divided in two groups, and each group was on duty for one month, in alternance. All those on service visited patients every day, regularly checking their state and treatment.

137 See Samama, *Les médecins dans le monde grec*.

138 See, in chronological order of the periods covered by these prosopographies: Lilie et al., *Prosopographie der mittelbyzantinischen Zeit, Erste Abteilung* (*641–867*); Lilie et al., *Prosopographie der mittelbyzantinischen Zeit, Zweite Abteilung* (*867–1025*); Trapp et al., *Prosopographisches Lexikon der Palaiologenzeit*.

139 The bibliographical list (arranged in chronological order of Byzantine physicians) and the abundant material provided in the following two works might prove useful as a starting point: Eutichiadis, *Ἡ ἄσκησις τῆς βυζαντινῆς ἰατρικῆς ἐπιστήμης καὶ κοινωνικαὶ ἐφαρμογαι αὐτῆς κατὰ σχετικὰς διατάξεις*, and Eutichiadis, *Εισαγωγή εις την Βυζαντινήν θεραπευτικήν*.

140 The *Typika* of Byzantine monasteries have been translated into English with thorough introductory studies in Thomas/Constantinides Hero, *Byzantine Monastic Foundation Documents*, 5 volumes For an analysis of their medical structures (from hospital to infirmary), see Birchler-Argyros, *Quellen zur Spitalgeschichte*. More recently, Bennet, *Medicine and Pharmacy in Byzantine Hospitals*, particularly pp. 5–31.

In the evening, four male and one female assistants were on duty and spent the night in the wards. The chief physician was responsible for the good management of the wards, including personalized contact with the sick.[141]

Byzantine manuscripts containing medical texts do not include much in terms of representations of physicians in the act of examining and treating patients. Apart from some images of physicians observing urine flasks, they seem to contain only one representation of a medical cabinet (below).

The exercise of medicine was ruled by legal regulations,[142] besides being implicitly or explicitly governed by ethical codes.[143] The Hippocratic *Iuramentum* (*Oath*)[144] is attested by a significant number of manuscripts in the Byzantine world,[145] in one of which the text has been written in such a way as to form a cross on the page.[146] The Christianization of the art of healing through the cult to the twins Kosmas and Damianos implied some deontological rules of conduct, mainly altruistic disinterested care, which was possibly best represented in Byzantium by hospitals. Prices of materia medica and other therapeutic products were regulated by imperial edicts.

### 6.7 *The Medical Place: the Hospital*

Considered for a long time as a major achievement of the Arabic world, the creation of the hospital is now attributed to Byzantium, where its origin has been first located among the Christian communities who fled civil society and regrouped in central Asia minor. Under the leadership of *Fathers of the Church* such as Gregory of Nazianzos (329/30–*c.* 390) and Basil (d. *c.* 364), who received a classical medical education, these communities necessarily had to take care

141 For these prescriptions, see the Greek text of the *Typikon* in Gauthier, "Le *Typikon* du Christ Sauveur Pantokrator," pp. 83–89, with the English translation by Jordan in Thomas/Constantinides Hero, *Byzantine Monastic Foundation Documents*, vol. 2, pp. 757–59. See also Volk, *Gesundheitswesen und Wohltätigkeit im Spiegel der byzantinischen Klostertypika*, pp. 136–44, and Birchler-Argyros, *Quellen zur Spitalgeschichte*, pp. 52–54. For other components of the medical practice, see below, with the different phases of the medical act and methods of treatment. For an evaluation of the medical services provided in Byzantine hospitals, see Horden, "How Medicalised Were Byzantine Hospitals."

142 Stathakopoulos, "On Whose Authority?" For psychiatry, specifically and for example, see Eftychiadis/Marketos, "The Legislation concerning Psychiatric Patients."

143 On this, see Garzya, "Science et conscience dans la pratique médicale de l'Antiquité tardive et byzantine."

144 Edition of the Greek text with English translation in Jones, *Hippocrates I*, pp. 298–301.

145 Diels, *Die Handschriften der antiken Ärzte I*, pp. 17–18.

146 See MS. Vat. Urb. gr. 64, fol. 116r abundantly reproduced.

of the health issues of their members. Though historical research first located the birth of hospital among these communities of Asia Minor as a service to the community,[147] it further identified its birth in Egypt and the first religious groups which spontaneously assembled in the desert in the 4th century.[148]

No hospital in Byzantium can be traced before the 10th century because of the limitations of excavated archaeological sites (and possibly also of the archaeological remains themselves), as well as the extant documentation. A comparison with Western hospitals might shed some light on the period preceding the 10th century in Byzantium, particularly because such a document as the so-called *Lorscher Arzneibuch* of the late 8th century gives clear evidence of contacts with the Byzantine world.[149] The so-called *Plan of St. Gall*, which was not the plan of the 8th-monastery, but a project for a monastery to be possibly built, is significant: it included a house for the physician in residence, a pharmacy, a ward for critically ill individuals, and a room for bloodletting. There was also a kitchen for the preparation of food for the hospitalized members of the community, a bath, and a chapel, with a garden for medicinal plants.[150]

In Byzantium, the hospitals that we know of were created by the imperial authority, and had very different sizes (from twelve to hundreds of beds). They were funded by an endowment, and had their organization regulated up to the very last detail by their act of foundation (*typika*).[151] These documents stipulated the number of physicians to be present in the hospitals, their ranking, and their titles, together with their duties and salary. They also explicitly determined the number of assistants and their rounds, and any other element of their duties as well as the available material. One such hospital was that of the *Pantokrator* in Constantinople, founded by Emperor Ioannes II Komnenos (1087–1143) in 1136. Another, later, one is the so-called *Xenodocheion tou Krali* named after the king (*Kral*) of Serbia Stefan Uroš II Milutin (reign. 1282–1321), which flanked the monastery of St. John Prodromenos (St. John Baptist) in the

147 Miller, *The Birth of the Hospital in the Byzantine Empire*.

148 Crislip, *From Monastery to Hospital*. For a reflection on the birth of the hospital, see Horden, "The Earliest Hospitals in Byzantium, Western Europe, and Islam."

149 Edition of the Latin text in Stoll, *Das Lorscher Arzneibuch*. For traces of contacts with Byzantium, see for example the prayer to Kosmas and Damianos (fol. 5r = pp. 64–65 in Stoll's edition).

150 Publication of the plan in Horn/Born, *The plan of St. Gall*.

151 For a hospital *typikon* (*Pantokrator*), see Gautier, "Le typikon du Christ Sauveur Pantocrator," with the Greek text and a French translation; for an English translation, see Jordan, "no. 28. Pantokrator."

Petra neighbourhood of Constantinople. In the mid-14th century, the complex of the monastery and the hospital included a library, where most of the earlier extant copies of Dioscorides, *De materia medica*, were preserved and a new edition of the text was made. There was also a school, which became the last university of Byzantium and was illustrated by John Argyropoulos before the capture of Constantinople by the Ottoman troops (above). It is possible that the hospital, the library and the school closely collaborated. The clinical experience of the hospital was recorded in writing and provided a basis for the validation of canonical texts. The up-to-date handbooks newly generated in this way were reproduced by the scribes working in the scriptorium. Teaching probably used the resources of the library and built on the experience gained from the practice in the hospital. All elements formed an organic centre for medical care and learning.

## 7 Nosology

As was the case for the processes of health, illness and therapy, anatomy in Byzantium was derived from Galen, in spite of the approximations and shortcomings that were not revealed until Andreas Vesalius (1514–1564) and *De humani corporis fabrica* (*On the Making of the Human Body*) (1543). No representations of the human skeleton and the internal organs can be found in Greek manuscripts; they can be found, instead, if sometimes in a highly schematic form, in Arabic codices where the circulatory system also appears. Physiology was analyzed in humoural terms according to the quaternary system codified at the time of the Hippocratic physicians (and much earlier), with blood, phlegm, black bile, and yellow bile. As in Hippocratic medicine, these four physiological fluids were placed in relation to the four elements of the world (air, water, earth and fire) and their qualities (hot, cold, dry and wet), with the latter associated in pairs of contraries (hot and cold, and dry and wet). They were also linked to the four ages of life, the four seasons, and the orientations according to the four cardinal points,[152] on the basis of a logic of the tetrad, which was widely diffused in antiquity.[153]

152 For a presentation of Galen's synthesis and interpretation of the Hippocratic system (which provided the basis for Byzantine medical thinking on this point), see Siegel, *Galen's System of Physiology and Medicine.*

153 Several Byzantine manuscripts contain, however, short texts about seven, rather than four, ages of humans.

### 7.1 *Etiopathology*

As in classical antiquity, pathologies were attributed to disturbances of the humoural components of the body, whether this disturbance was quantitative (excess or deficiency of a humour) or qualitative (alteration of a humour). Pathogenesis also included different causal agents: environmental conditions according to the traditional Hippocratic theories best represented by the treatise *De aere, aquis et locis* (*Airs, Waters, Places*); epidemics (the exact nature of which was not exactly known); major natural phenomena, including earthquakes and the impact they often had on public health; major and sudden meteorological phenomena, together with astral influences, including the phases of the moon.[154] Byzantine manuscripts contain numerous calendars, tables, and short texts about the impact of weather conditions and celestial bodies on the sublunary world,[155] particularly human health, according to an implicit theory probably aiming to account for the empirical knowledge of the impact of such phenomena on living creatures, particularly plants.[156]

### 7.2 *Nosography*

The pathologies affecting Byzantine populations were described in the Galenic literature, completed by specialized treatises, whether they were those of the Hippocratics (among others on embryology, peri-natology, and pediatrics), Soranos (on gynecology) or, much later, Demetrios Pepagomenos, *De podagra*, and Neophytos Prodromenos, *De dentibus*,[157] among many examples.

The translation of Razi's treatise on measles and smallpox into Greek suggests that the corpus of medical literature was adapted over time not only as the result of the availability of new material, but possibly also as the result of medical needs. In the case of the introduction of new material, this could be taken as an indicator of the appearance of a new pathology according to the correlation postulated above. Major skeletal traumatology received much attention as will be seen in the discussion of therapy below.

### 7.3 *Diagnosis*

The diagnosis of medical conditions relied mostly on the analysis of urine and the pulse. For the former, the colour, the consistency, and possible deposits and layers were scrutinized and interpreted by means of specialized treatises from

154 On this, see chapter 5 of this volume.

155 Many of these manuscripts are listed in the *Corpus Codicum Astrologorum Graecorum*.

156 See also chapters 6 and 13 of this volume.

157 Neophytos Prodromenos, *De dentibus*, ed. Kouzis.

Pseudo-Galen[158] to the more recent ones possibly of Arabic or Persian origin.[159] Some manuscripts contain tables connecting the many colours that urine could have with the medical conditions responsible for each such colour. In others, instead of tables, the flasks used to collect urine (*matula*) were represented; they were full of the urine, each one with a colour that corresponded to one or more pathology.[160] In the margin of some manuscripts, a man is represented holding in his hand one such flask and examining the colour of the urine.[161]

Pulse analysis was more complex.[162] It was based on the sphygmological treatises of Galen,[163] which distinguished three dimensions to the pulse (not only length and width, but also depth) and described multiple pulse variations according to these three parameters, including the interval between diastolic phases. Each type of pulse received a specific name and was placed in relation to one or more pathology.

## 8 Surgery, Gynecology, Obstetrics

Much of the medical literature transmitted—or generated—by the Byzantine world is about therapy, indicating that the care for patients was the main goal of medical activity. Treatment methods were of three major kinds: surgery, bleeding and cupping, together with remedial therapies.

158 Edition in Kühn, vol. 19, pp. 574–601 (*De urinis* [*On urine*]), 602–8 (*De urinis compendium* [*Compendium on urine*]), 609–28 (*De urinis ex Hippocrate, Galeno et aliis quibusdam* [*On urine from Hippocrates, Galen and some others*]).

159 Touwaide, *Medicinalia Arabo-Byzantina*, pp. 76–77.

160 For example, MS. Bologna, Biblioteca universitaria, 3632, fol. 51. For more examples, see MacKinney, *Medical Illustrations in Medieval Manuscripts*, pp. 10–14 with related colour plates. Also, Jones, *Medieval Medicine in Illuminated Manuscripts*, particularly pp. 43–57.

161 An example of this is MS. Paris, Bibliothèque nationale de France, gr. 2294, fol. 71v.

162 See Deichgräber, *Galen als Erforscher des menschlichen Pulses*, and, more recently, Bacalexi, "*De pulsibus ad tirones*," and Boylan, "Galen: On Blood, the Pulse, and the Arteries."

163 Edition in Kühn, vol. 8, pp. 453–92 (*De pulsibus ad tirones* [*On the pulse for beginners*]), 493–765 (*De pulsuum differentiis libri IV* [*On the differences of the pulse*]), 766–961 (*De dignoscendis pulsibus libri IV* [*On the knowledge of the pulse*]); 9, pp. 1–204 (*De causis pulsuum libri IV* [*On the causes of the pulse*]), 205–430 (*De prasagitione ex pulsibus libri IV* [*On prediction from the pulse*]), 431–549 (*Synopsis librorum suorum sedecim de pulsibus* [*Synopsis of his 16 books on the pulse*]). For an English translation with an introduction and thorough analysis of Galen's sphygmological treatises, see Johnston/Papavramidou, *Galen on the Pulses. Translations of his Three Short and Four Long Treatises*.

### 8.1 *Surgery: Major Interventions*

Surgical techniques were summed up by Paul of Aegina who seems to have been a competent and successful practitioner.[164] The range of surgical interventions performed by Byzantine physicians was vast, from the ablation of bladder stones to the possible separation of Siamese twins.[165] Although no Greek manuscript is known to contain representations of surgical instruments, we can get an idea of the Byzantine surgical *instrumentarium* through instrument representations in the manuscripts of the Andalusian surgeon abu al-Qasim al Zahrawi (936–1013), with scalpels, saws, trephines, cauteries, tweezers, needles, and other necessary instruments.[166] In his treatise on surgery, al Zahrawi—most commonly known in the West as Albucasis—followed Greek sources so closely that the illustrations of his work help to clarify such a text as Paul of Aegina's. The same is valid for the surgical work and the illustrations of the late medieval French surgeon Guy de Chauliac (ca. 1300–1368), based on Arabic sources and, through them, on Greek material.[167]

### 8.2 *Anaesthesia*

A question much discussed in medico-historical literature related to surgery is anaesthesia. Dioscorides, *De materia medica*, provides unambiguous information on this matter, with both local and general agents ranging from sedatives to more powerful substances able to provoke a temporary loss of consciousness. Such agents were administered by means of sponges imbued with the anesthetic substance and called for that reason *spongia somnifera* (Somniferous sponges).[168]

### 8.3 *Bleeding and Cupping*

Bleeding and cupping aimed to eliminate the excess of blood supposed to be responsible for pathologies, or to attract pathologic matter to one point of the body in order to further extract it from its seat.[169] Both techniques of depletion and derivation were complemented by vomiting provoked by means of emetics, and purging with cathartics, aimed at eliminating pathological substances from the body. All such techniques were described in treatises completed by

164 On Paul of Aegina as a successful surgeon, see for example, Tabanelli, *Studi sulla chirurgia bizantina.*

165 Pentogalos/Laskaratos, "A Surgical Operation Performed on Siamese Twins."

166 Spink/Lewis, *Albucasis*.

167 McVaugh, *Guigonis de Caulhiaco* (*Guy de Chauliac*)*, Inventarium sive Chirugida magna*.

168 See, for instance, Kalantzis/Trompoukis/Tsiamis/Lascaratos, "The use of analgesics and hypnotics in the ancient Greek and Byzantine era."

169 On bleeding, see Brain, *Galen on Bloodletting*.

shorter tracts (actually calendars) dealing with the times when these interventions should be performed. Many of these tracts also circulated independently, including in manuscripts mostly devoted to astrology.

### 8.4 *Traumatology and Structural Disability*

Besides light and heavy interventions requiring opening the body, Byzantine physicians were able to treat fractures and minor traumas. They could also remedy structural impairment and the reduction of the function and mobility of members through what is now known as physiotherapy, using mechanical force and movement. Heavy and light surgery, as well as traumatology included multiple techniques of bandaging to which some specific treatises were dedicated. Hippocratic texts were used to this end, particularly in the version of Apollonius of Citium (1st cent. BCE), which was illustrated as in the so-called 10th-century *Manuscript of Niketas*, including representations of post-surgical and post-traumatic bandaging.[170]

### 8.5 *Gynecology and Obstetrics*

Gynaecology and obstetrics, which might have been the almost exclusive province of women, were the object of specialized treatises (including the so-called *Metrodora*[171] known through a unique manuscript,[172] and attributed to an enigmatic author whose historicity is far from firmly attested[173]). They were not limited to the follow-up of the generative cycle of women from menarche to menopause, nor the monitoring of pregnancy and childbirth together with perinatal care, but they also included anticonceptional practices and abortion methods. These were well attested to in the written documentation, although a large part of such information might have been transmitted mostly in oral form. Whereas these practices have much drawn the attention of research,[174]

170 This is MS. Florence, Biblioteca Medicea Laurenziana, plut. 74.7. For a recent, comprehensive study of the manuscript and its illustrations, see Bernabò, *La collezione di testi chirurgici di Niceta.*

171 Edition of the text by Kouzis, "ΙΑΤΡΙΚΟΙ ΚΩΔΙΚΕΣ. Metrodora's Work."

172 MS. Florence, Biblioteca Medicea Laurenziana, plut. 75.3.

173 Touwaide, "Metrodora." See also Congourdau, "Métrodôra et son oeuvre."

174 On anticonceptionals and abortifacients, see Keller, *Die Abortiva*; Riddle, *Contraception and Abortion*; and Kapparis, *Abortion in the Ancient World.*

Byzantine gynecology and obstetrics in general have been little studied,[175] contrary to their classical Greco-Latin and Latin medieval equivalents.[176]

## 9 Pharmacotherapeutics

### 9.1. *Materia Medica*

Remedial therapy was probably the most important source of relief for ailing patients. The natural substances to be used as ingredients for the preparation of remedies (of plant, animal or mineral origin, together with some manufactured products) were known mainly through Dioscorides, *De materia medica*, complemented by Galen, *De simplicium medicamentorum temperamentis ac facultatibus* 6–8 (*On the Mixtures and Properties of Simple Medicines*),[177] which was combined *in toto* or *in parte* with Dioscorides' text in some manuscripts.[178] In many manuscripts of Dioscorides, *De materia medica*, the plants used as medicines were represented by coloured illustrations.[179] Being encyclopedic in nature, *De materia medica* was soon reduced to convenient compendiums as the so-called *Herbal* of the *Vindobonensis*.

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175 As an example of the all too rare research on the topic, see López Pérez, *Ginegología y patología sexual feminina en las colecciones Médicas de Oribasio*.

176 For the literature of classical antiquity, see for example the collection of texts (mostly Greek) with facing German translation assembled in Schubert/Huttner, *Frauenmedizin in der Antike*. Among the multiple studies on the topic, see for example Dean-Jones, *Women's Bodies in Classical Greek Science*, and Mayhew, *The Female in Aristotle's Biology*. For the Latin Middle Ages, seee the many works by Monica Green, particularly *Women's Healthcare in the Medieval West*, which collects several essays by the author, in addition to a critical edition (with facing English translation and an introductory study) of the treatise traditionally identified as *Trotula*-the western equivalent of Metrodora: *The Trotula. A Medieval Compendium of Women's Medicine*. See also Green, *The Trotula. An English Translation of the Medieval Compendium of Women's Health* (which offers only the translation), and *Trotula. Un compendio medievale di medicina nelle donne* (which contains the Latin text with facing Italian translation, together with a substantial introduction).

177 Edition of the Greek text in Kühn, vol. 11, pp. 789–890, and 12, pp. 1–158. For an inventory of the manuscripts see Petit, "La tradition manuscrite du traité des *Simples* de Galien" (with some mistakes).

178 The best representative of this is Vat. gr. 284 studied in Touwaide, "Un recueil grec de pharmacologie du X^e^ siècle illustré au XIV^e^ siècle."

179 Touwaide, "Les manuscrits illustrés du *Traité de matière médicale* de Dioscoride."

The range of materia medica changed over time. The classical texts above were rapidly transformed as the lists of *quid pro quo* indicate. Such lists aimed to substitute expensive, rare or non-native plants, or, more simply, plants seasonally or locally unavailable, with others, local, and more easily or seasonally accessible.

Non-native plants of the Mediterranean environment that had been acclimated might not have been cultivated after the 6th century. By that time, drugs obtained from Arabian, Indian, and Chinese plants probably became less frequent on the market or were too expensive for a regular use, even though Byzantium had access to Chinese products as early as the 6th century as is demonstrated by the contemporary acquisition of silk worms. The rise of the Arabic empire provoked a new expansion in the range of medicinal substances. After it conquered vast portions of territory from the Mediterranean to India, Baghdad traded the natural products coming from its empire. As early as the 8th century it introduced non-native plant species into the Mediterranean environment, particularly into Andalusia, and later into Sicily. This expansion is reflected in Byzantine medical literature. The eastern materia medica present in Dioscorides' text that had been abandoned in the early Byzantine centuries were reintroduced. This can be observed in the 11th-century copy of Dioscorides, *De materia medica*, preserved at Mount Athos.[180] This is also the case with a treatise such as Symeon Seth, *De alimentorum facultatibus* (*On the Properties of Foodstuffs*), describing the range of foodstuffs, plants, and other products used in Byzantium in the 11th century, including items from the East.[181]

After the fall of Baghdad in 1258 and the end of the Latin Occupation of Constantinople in 1261, oriental plants and their derivatives might have been more abundant than previously in the capital as the many bilingual lexica (Greek and Arabic or Persian) suggest. New manufactured products such as sugar or camphor obtained by distillation were introduced at that time.

## 9.2 *Toxicology*

All the late antique encyclopedias and many medical works of the subsequent periods include a section on venoms and poisons.[182] At some point in time

180 See above p. 371 about this manuscript (Ω 75 of the Great Lavra Monastery at Mount Athos, Greece).

181 See above p. 371 on Symeon Seth. Edition of *De alimentorum facultatibus* by Langkavel.

182 On this literature, see Touwaide, "Les poisons dans le monde antique et byzantin."

during the early centuries of Byzantium, two small treatises on these topics were integrated into the *corpus Dioscorideanum*.[183]

This presence of toxicology in the Byzantine medico-pharmaceutical literature should not be attributed to a special concern or an omni-present danger (particularly venomous animals). It should rather be seen as a sequel of the interest in toxicology during the Alexandrian period, when the action of venoms and poisons on the human body was used as a heuristic device for the understanding of the action of medicines. In Byzantium, toxicology was no longer used as such: its part on poisons constituted an appendix to the study of materia medica, and both parts (poisons and venoms) were justified in any work on therapeutics.

The abundant manuscript tradition of the two poems by Nicander (2nd [?] cent. BCE) (*Theriaka* and *Alexipharmaka*, on venoms and poisons, respectively) in Byzantium hints at an interest in venoms and poisons exploited as a gory topic. It might be significant that Maximos Planoudes edited, and personally copied, the two poems.[184]

### 9.3 *Describing/Explaining the Action of Drugs*

A joint analysis of the manuscript tradition of both Dioscorides, *De materia medica*, and Galen, *De simplicium medicamentorum temperamentis ac facultatibus* (*On the mixtures and properties of simple medicines*) brings to light repeated attempts to reconcile the two treatises in a unique synthesis.[185] None of the resulting assemblages seems to have generated new copies in Byzantium.

In addition, the manuscript tradition of Dioscorides' treatise (whatever its form) is much more abundant than that of Galen. Significantly enough, this

183 On these two pseudo-dioscoridean treatises, see Touwaide (ed.), *Les deux traités de toxicologie attribués à Dioscoride. La tradition manuscrite grecque, édition critique du texte, traduction et index*, 5 vols., and the following two studies: "L'authenticité et l'origine des deux traités de toxicologie attribués à Dioscoride:, and "Les deux traités de toxicologie attribués à Dioscoride. Tradition manuscrite, établissement du texte et critique d'authenticité."

184 Florence, Biblioteca Medicea Laurenziana, MS. plut. 32.16.

185 The case of the MS. Vat. gr. 284 of the 10th century is significant of these attempts with a re-arrangement of Dioscoride's text according to that of Galen. See Touwaide, "Un recueil grec de pharmacologie du Xe siècle illustré au XIVe siècle: le *Vaticanus graecus* 284." No less significant, the Paris. gr. 2183 of the 14th century, in which Galen's passages related to the identification and quantification of the action of drugs, have been added in the margins of the manuscript facing Dioscorides' corresponding text. See Touwaide, "The Salamanca Dioscorides."

difference is constant throughout the centuries, even though the preserved production fluctuated according to the periods, and preserved codices do not reflect by an means actual production.

Both facts are a clear indication of a preference for *De materia medica*, which must be interpreted considering the difference in content of both works.[186] Although this might be seen—and has been—as a sign of a disaffection of theory (that is, Galen) in favor of a simpler manualistic (Dioscorides, particularly such form as the *Alphabetical Herbal*), it might be that it was, instead, a manifestation of a holistic approach to therapeutics, particularly to plants. This would hint at a concept of the action of plants that could not be reduced to a materialistic, quantifiable system as that of Galen, but was rather viewed as an irreducible complex of activities that could be subsumed, however, by general, more encompassing, therapeutic principles (δύναμις) as in Dioscorides. This concept, in turn, could account for a great diversity of actions and modes of actions resulting in a broad range of applications.

## 9.4 *Gardens of Medicinal Plants*

In 2007 archaeologists discovered a large site 20 km west of Istanbul, which they identified as the ancient Bathonea (now Küçükçekmece Lake).[187] Destroyed during the 6th century (620–640), the site included a structure to which I shall return—apparently a pharmaceutical laboratory—, on the side of which there was a garden. There, archaeologists identified traces of plants for which medicinal uses are known. Because of the nature of the structure, the archaeologists interpreted this as a garden of medicinal plants.

If the interpretation of the archaeological site of Bathonea is correct, the garden produced plants to be treated in the laboratory. The case of monasteries in the West might be similar in certain ways, particularly the Carolingian monastery of Lorsch (8th century) complemented with the so-called *St. Gall plan* for the construction of such a monastery. Though of modest dimensions with a limited range of species (no more than 16),[188] the *St. Gall plan* provides

186 See above, p. 306–8.

187 No report of the find seems to have been published thus far. The site, together with the interpretation of the artefacts recovered from the site and the results of the laboratory analysis of the content of amphorae, seem to have been revealed to the world only through an article in the Turkish newspaper *Hürriyet* dated October 19, 2016 and later retransmitted by international media.

188 For the plan and a thorough study, see Horn/Born, *The plan of St. Gall*. For the garden of medicinal plants, see vol. 2, pp. 181–84, with a list of the plants on p. 181. As a complement, see Niederer, *Der St. Galler 'Botanicus.'*

evidence of a garden for medicinal plants to be created in a monastic milieu. In the context of exchanges between Byzantium and the Carolingian world, it might be hypothesized that this model for a garden of medicinal plants adjacent to a structure for the care of the sick might have come from Byzantium.[189] Such a model would not be much different from the Bathonea one, the difference lying in the scale of the production, and in the form and delivery of the medicines. Bathonea could possibly have been a laboratory for a production of medicines for long-term conservation that might be compared to modern prescription drugs, possibly for a wide commercial distribution.[190] The monasteries, instead, would have had a small laboratory (at least in these early times), where prescription remedies were prepared on an individual basis for the immediate use of the patients in the wards of the monastic infirmary. Whatever the case, propagation of plants is attested in a nursery in Egypt, though in an earlier period.[191]

## 9.5 *Pharmaceutical Activity*

No study is available on the pharmaceutical activity in Byzantium.[192] The title of *Myrepsos* given to Nicholas, the author of the *Dynameron*, suggests that Nicholas specialized in the preparation of medicines.[193] It also suggests that there might have been in Byzantium a profession not so different from the medieval *apothecarius*, according to a transformation of the medical practice characterized by the legal difference made between physicians and pharmacists. Such difference is already perceptible in the Arabic world.[194] It is explicit in the so-called *Constitution of Melfi* promulgated in 1231 by the emperor

189 In this sense, see also Talbot, *Byzantine Monastic Horticulture*.

190 See below, p. 400.

191 See Kenawi/Macaulay-Lewis/McKenzie, "A commercial nursery," about a site originally built sometimes in the 1st century BC, restored after mid-1st century BC, and used until the 2nd or 3rd century CE.

192 The large study by Kritikos/Papadakis, "Contribution à l'histoire de la Pharmacie chez les Byzantins" is mostly a descriptive survey of available texts on the topic. Schulze, *Die pharmazeutische Fachliteratur in der Antike* is similar. The general history of pharmacy from antiquity to the end of the Middle Ages by Schmitz, *Geschichte der Pharmazie*, pp. 205–17 on Byzantium, is mostly introductory in nature. It might be useful to consult a work as the following, though referred to Antiquity: Russo, "I preparatori di farmaci nella società romana." See, neverthelss, Rance, "An Unpublished Byzantine Medical Fragment (Parisinus suppl. gr. 607): Pharmaceutical Knowledge and Practice in Tenth-century Constantinople," and the hospitals formularies published in Bennett, *Medicine and Pharmacy in Byzantine Hospitals*, pp. 162–221.

193 The term *myrepsos* should not be interpreted as referring to perfumery because of its first element. See Kriaras, *Λεξικό*, vol. 11, p. 152, *sub verbo*.

194 See Schmitz, *Geschichte der Pharmazie*, pp. 268–70.

Frederick II von Hohenstaufen (1194–1250),[195] which prohibited physicians entering into a society with pharmacists.

### 9.6 *Forms of Medicines*

Remedies originally took two forms: simple and compound. Whereas the former were mainly made of an active substance mixed with an excipient aimed to make it possible to absorb the medicinal substance in internal use or to apply it to the skin in external use, the latter combined a varying number of ingredients according to formulae such as those described by Galen in *De antidotis* (*On Antidotes*).[196] Compound medicines had the advantage over simple ones of being long-conservation products. Their development from the 1st century CE to Galen's period might reflect the increased urbanization during that time together with a loss of contact with the natural environment. It might be the case that a similar phenomenon happened in Byzantium with the development of Constantinople. In rural areas, however, it is highly probable that simple medicines continued to be used as before.

### 9.7 *Formulae for Medicines*

The formulae for the remedies to be administered to patients were listed in different works, from such general lists as Galen, *De compositione medicamentorum secundum locos* (*On the Composition of Medications according to Places*), describing medicines according to the affected parts of the bodies, that is, by pathologies,[197] and *De compositione medicamentorum per genera* (*On the Composition of Medications according to Kinds*), listing medicines by pharmaceutical forms,[198] or the formularies of hospitals,[199] to more specialized treatises devoted to one infection (for example gout) or general symptoms (often fever).

Such works went together with anonymous lists of formulae for medicines to be found in manuscripts, which were probably generated by the process of agglutination in medical milieux,[200] and are better known by their post-Byzantine examples identified as *iatrosofia*.[201] Lists as those, which were characterized by their fluidity, often enumerated remedies according to the parts

195 For the Constitution of Melfi, see Hein/Sappert, *Die Medizinalordnung Friedrichs II*, and Zecchino, *Medicina e sanità nelle Costituzioni di Federico II di Svevia (1231)*.

196 Edition of the Greek text in Kühn, vol. 14, pp. 1–209.

197 Edition by Kühn, vol. 13, pp. 1–361.

198 Edition by Kühn, vol. 13, pp. 362–1058.

199 For a recent study of some such formularies and the edition of some texts and a precise description of others, see Bennett, *Medicine and Pharmacy in Byzantine Hospitals*.

200 For an example of this, see MS. Vat. gr. 299.

201 The field of *iatrosofia* is still largely unexplored. For a census of many of them, see Karas, *Οἱ Ἐπιτσῆμες στήν Τουρκοκρατία. Χειρόγραφα καὶ ἄντυπα*, vol. 3. *Οἱ Ἐπιστῆμες τῆς Ζωῆς*.

of the body or the organs, which were usually ordered *a capite ad calcem* (*from head to heels*).

Many of the compound remedies listed in this vast textual corpus were identified by the name of the preparer who allegedly created them. Attributions of formulae to famous preparers might have been fictitious for commercial purposes, resulting in the development of remedies now identified as *substandard drugs*.[202]

## 9.8 *Pharmaceutical Technique*

The pharmaceutical technique became more complex over time, particularly under the influence of the Arabic world, which created new forms of medicines based on sugar, and introduced distillates. The whole range of such new pharmaceutical forms in the late-Byzantine period was listed by Nicholas Myrepsos in the *Dynameron*, which describes the many remedies used at that time according to their form.

Treatises on medicines and pharmaceutical forms were often followed by short lists of weights and measures specifically designed for medico-pharmaceutical use.[203]

## 9.9 *Pharmaceutical Instruments and Drug Containers*

In the structure adjacent to the garden discovered on the site of Bathonea in 2007,[204] archaeologists found spatulas, mortars of several sizes, pestles, and a furnace, in addition to medical instruments. Outside, they identified the garden mentioned above.

Drug containers were briefly described by Dioscorides in the introduction of *De materia medica*.[205] They were differentiated according to the nature of the substances to be preserved (leaves, roots or flowers of plants, oils and unguents, parts of animals or liquids of any kind), and were earthenwares, glass vials, sheets of papyrus or light pieces of fabric, boxes made of different kinds of wood (particularly non-porous species), and metallic boxes.

The development of pharmaceutical technology went together with a transformation of pharmaceutical containers. The Arabic world developed the technique of glazed ceramic, which prevented the process of oxidation typical of porous earthenware and allowed for a better preservation of liquid or

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202 For such an example (though in the Arabic medical literature), see Kahl, "A Note on Substandard Drugs."

203 On this specialized literature, see Schilbach, *Byzantinische metrologische Quellen*, and *Byzantinische Metrologie*.

204 On this site, see above, p. 396.

205 See *Praefatio*, 6, ed. Wellmann, vol. 1, pp. 3, l. 19–4, l. 3.

semi-liquid substances. These recipients-known as *albarelli*-were cylindric with concave sides. Both their manufacturing techniques and forms were introduced into Byzantium. They can be observed in some representations of medical scenes where drug containers are stored on a shelf or on the table beside a patient lying in bed.[206]

## 9.10 *Drug Production*

In the Bathonea structure, archaeologists recovered no less than 700 small bottles similar to amphorae, all made at the same time. Their high number suggests that this structure was not that of an apothecary dispensing prescription medicines, but a true pharmaceutical laboratory producing great quantities of medicine, apparently for wide distribution.[207]

## 9.11 *Drug Dispensation*

We have no knowledge of apothecary shops in the Byzantine world, or of laboratories where *pharmacists* prepared *prescription drugs*. The representation of a medical cabinet in a 14th-century manuscript containing the *Dynameron* by Nicholas Myrepsos shows a physician in the act of examining a patient, while another individual of smaller dimensions and most probably also of inferior rank—maybe a preparer—handles a pestle over a large mortar, probably to crush and mix drugs; in the background, containers similar to albarelli can be seen on a shelf, possibly holding herbs or medicines.[208]

In large cities, it is highly probable that physicians had to buy the medicinal plants they needed on the local market. These plants would have been collected in the wild by providers known from antiquity onwards as *root-cutters*. These providers of herbs might not have received any formal education, but were familiar with the plants through general or oral tradition, or possibly from members of their own family. In the country side plants would have been procured directly from the wild or from orchards close to dwellings that might have been managed by the women of the household, perhaps under the supervision of the elderly.

206 For the albarelli on a shelf, see the MS. Paris. gr. 2243, fol. 10v, abundantly reproduced, including in Lazaris, "Scientific, Medical and Technical Manuscripts," fig. 32 (in colour). On the materiality of medicine and pharmacy, see, for example Grünbart/Stathakopoulos, "Sticks and Stones: Byzantine Material Culture," and, more recently and more specifically, Łsjtsr/Południkiewicz, "Medicinal Vessels from Tell Atrib (Egypt)"

207 A laboratory analysis of residues collected from these vials has made it possible to isolate chemicals, which have been identified with pharmacological substances now used to treat depression and cardiac conditions.

208 MS. Paris. gr. 2243, fol. 10v.

### 9.12 *Evaluating the Efficacy of Ancient Remedies*

The efficacy of remedies used in the Old World (including in Byzantium) has been—and still is debated. Efficacy is often attributed to the placebo effect. For the Byzantine world, this alleged effect was possibly reinforced by the supposed accompaniment of prayers, charms, incantations, and other magical texts. All this is not substantiated by textual evidence. Contrary to what is often stated and might be thought, prayers and other similar elements are not common in codices. Instead, interpretation of this kind is increasingly contradicted by ongoing ethnopharmacological research, whether it is on the basis of ancient texts or on current traditional practice.

The fact is that the methods currently used to evaluate the efficacy of ancient remedies (including clinical trials) are based on a reductive approach that cannot account for the range of physiological activity possibly generated by plants or other natural substances used as therapeutic agents. Recent research on ancient texts that reproduced exactly the procedures used for the preparation of a medicine (including the time period allowed between the preparation of the remedy and its administration) has shown that the therapeutic action(s) attributed to that medicine are real.[209] The diffusion of the pathogen was reduced and could be exactly measured, and the preparation and its effect(s) could also be duplicated.

To this limited case, one could add all the ongoing ethnopharmacological research on the therapeutic properties of single plants known through contemporary oral tradition, which often corresponds to ancient written traditions known through texts, and is validated by clinical experimentation. This may not, however, take the form of the protocol of multi-year clinical trials as standardized by current legislation and commonly accepted as best practice.

## 10 Orientations for Future Research

The survey above reflects traditional historiography, the most recent advances, and also the shortcomings of current research in Byzantine medical history. It also identifies—at the very least by default—the areas to be explored, possibly starting with the cataloguing of manuscripts containing medical texts, with

209 See, for instance, Watkins et al., "Anglo-Saxon pharmacopoeia revisited," and Watkins et al., "Antimicrobial assays of three native British plants used in Anglo-Saxon medicine." The results of this research programme in experimental historical drug discovery exposed in these two publications of 2011 and 2012, respectively, have been further confirmed in 2015 in Harrison et al., "A 1,000-year-old antimicrobial remedy."

the identification of those texts focussing not only on Hippocrates, Galen, and the treatises by major and known medical writers, but also on the innumerable anonymous writings, of differentiated length, literary quality (or the lack thereof), and apparent interest compiled by practitioners of all origin, education and qualification, who were in direct contact with patients and who wrote down the results of their daily experience of medicine.

Equally important and urgent—but certainly more demanding in both conceptual and financial terms—, is the development of appropriate methods for detecting, collecting, analyzing, and interpreting relevant archaeological remains. Such material may be hardly perceptible, even invisible, but nonetheless present in the form of pollen, residues in containers of all sorts, together with DNA to be captured from skeletal and other organic material. This would all add factual evidence to textual information, and validate written data.

The introduction and current development of modern laboratory techniques aimed at accurately analysing physical evidence should be strongly encouraged. Collecting physical evidence requires accrued awareness and attention, together with appropriate techniques, in the excavation of archaeological sites, to collect significant material that may escape attention in field work, and also in museum collections, to avoid deterioration and contamination in their storage and restoration/conservation units.

The diffuse, yet clear presence of, and references to, medicine in multiple components of ancient daily life and productions of all kinds should be systematically traced, collected, and assembled in a coherent corpus. Laws and legal documents, philosophical treatises, historical prose (including accounts of cases) and poetry (with medical imagery), popular narratives and tales, and proverbs and other sapiential literature, in addition to the religious discourse (from scriptural interpretation to homilies and psalms), and non-medical forms of treatment, all contributed to the building of a medical culture that was outside the scope of this survey, but provide the substance for a reconstruction of the imaginary of health, disease, treatment, and medicine, with its possible psychological impact and its repercussions on the experience of life.[210]

210 There are several works exploring the topic of medicine in literature, history, and epistolography, for example. Among others (in chronological order of publication): Leroy-Molingen, "Médecines, maladies et remèdes dans les Lettres de Théophylacte de Bulgarie"; Leven, *Medizinisches bei Eusebios von Kaisareia*; Ieraci Bio, "Notazioni mediche nella Vita Nili," with a more general study by the same: "La letteratura medica bizantina: tipologie e testi"; and Timplalexi, *Medizinisches in der byzantinischen Epistolographie (1100–1453)*. To this, one might add such non-medical form of treatment as music, on which see Horden (ed.), *Music as Medicine. The History of Music Therapy Since Antiquity*, and some essays in Horden, *Cultures of Healing*.

Together with such micro-analyses, macro-syntheses are needed, in conjunction with the assemblage of available information from all material in a dynamic way, so as to adhere as closely as possible to the fluidity and plasticity of the reality under study. This would result in a living reconstruction reflecting the reality and complexity of Byzantine medicine, and also of the health, illnesses, epidemiology, and nutrition of the populations in the empire during its millennium of existence.

CHAPTER 11

# Veterinary Medicine

*Stavros Lazaris*

The first ground-breaking works in the history of science appear in the last quarter of the nineteenth century, with for example the *Bullettino di bibliografia e di storia delle scienze matematiche e fisiche* (1867–1887) under the direction of prince Baldassarre Boncompagni, the *Bibliotheca Mathematica* (1884–1914) by Gustaf Hjalmar Eneström, or the *Abhandlungen zur Geschichte der Mathematik* (1877–1913) by Moritz Cantor. These are but a few names among the numerous scholars who contributed to the foundations of the history of science. Some focussed specifically on ancient sciences, especially Greek. For instance, Paul Tannery, a tobacco engineer turned specialist in Greek studies greatly increased our knowledge of Greek science, together with Marcellin Berthelot, a historian of ancient chemistry. The work of these pioneers contributed significantly to the history of science and ensured it would become a distinct field that could stand on its own.

Regarding the history of veterinary medicine, as a subject *per se*, apart from L. Moulé and his 'Histoire de la médecine vétérinaire' published in the *Bulletin de la Société centrale de médecine vétérinaire* between 1891 and 1910, one should mention works of H.-J. Sévilla[1] and E. Leclainche.[2] More recently, L. Bodson,[3] K.-D. Fischer[4] or R.E. Walker[5] are among the researchers who helped establish a rigorous framework for studies in the history of ancient veterinary medicine.

1 "Considérations sur les saignées pratiquées par les hippiatres grecs"; "Un régime alimentaire pour les chevaux maigres et exténués en Cappadoce"; "Le cardiaque et l'hydropique"; "L'art vétérinaire antique. Considérations sur l'hippiatrie grecque. Les affections et les syndromes pulmonaires sporadiques"; "L'hippiatrie byzantine du IV$^{\text{ème}}$ siècle. Ses sources orientales"; "L'hippiatrie byzantine au IV$^{\text{ème}}$ siècle. Ses topiques"; "L'hippiatrique byzantine au IV$^{\text{ème}}$ siècle. Ses méthodes thérapeutiques. La purgation"; "Notes d'histoire sur l'art vétérinaire antique. Les formes pharmaceutiques des hippiatres grecs."

2 *Histoire de la médecine vétérinaire*; *Histoire illustrée de la médecine vétérinaire*.

3 For example: "La médecine vétérinaire dans l'Antiquité gréco-romaine. Problèmes, composantes, orientations"; "Panorama de l'histoire de la médecine vétérinaire." L. Bodson's bibliography is vast and is accessible here: <http://promethee.philo.ulg.ac.be/Zoologica/lbodson/bibl/>.

4 For example: "Ancient veterinary medicine: a survey of Greek and Latin sources and some recent scholarship."

5 "Roman veterinary medicine."

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Their work has been emulated and since the 1990s favoured the training especially of a new generation of researchers in veterinary medicine, and notably in hippiatric medicine in several countries both in Europe and North America. But the real rise in the study of veterinary medicine, ancient and medieval, took place at the turn of the twenty-first century. Since 2004, five conferences, related to the field, have taken place (Brest, 2004;[6] Catania, 2007;[7] Louvain-la-Neuve, 2011;[8] Lyon, 2014;[9] Munich, 2017.[10]) In parallel with these conferences, and gathering mostly philologists, archaeologists and historians, the year 2003 saw the organisation of a first international gathering at the French School of Athens on the prominence of Equidae in ancient societies.[11] It was followed by another in Montpellier in 2008,[12] and, one year later, by a third in Strasbourg, extended, this time, to medieval cultures.[13] Finally, it is worth mentioning three other conferences in this field. Two were organised in Arles to celebrate the 500th Anniversary of the Confrérie des Gardiens (28 April and 3–5 May 2012)[14] and another one in Lausanne.[15] Several PhD theses on the subject have been defended and published while others are underway.

Thus, we may agree that man's most noble achievement ('la plus noble conquête de l'homme'[16]) now occupies an increasingly prominent place in the field of ancient and medieval history. This is also the case with the topic of hunting (employing birds of prey and dogs).[17] But other animals remain overlooked in terms of the history of veterinary medicine. In fact, even though several other animals have attracted the interest of ancient veterinary doctors such as oxen, donkeys or camelids,[18] the preserved literature is very limited,

6 Cam (ed.), *La médecine vétérinaire antique*.

7 Ortoleva/Petringa (eds.), *La veterinaria antica e medievale*.

8 Doyen/Van den Abeele (eds.), *Chevaux, chiens, faucons*.

9 Gitton-Ripoll (ed.), *La trousse du vétérinaire dans l'Antiquité et au Moyen Âge*.

10 Sannicandro/Schwarzenberger (eds.), "Morborum et signa et causas praedicere curasque monstrare": *La medicina veterinaria nel mondo antico e medievale*.

11 Gardeisen (ed.), *Les équidés dans le monde méditerranéen antique*.

12 Gardeisen/Furet/Boulbes (eds.), *Histoire d'équidés : des textes, des images et des os*.

13 Lazaris (ed.), *Le cheval dans les sociétés antiques et médiévales*.

14 Gardeisen/Chandezon (eds.), *Équidés et bovidés de la Méditerranée antique: rites et combats—jeux et savoirs*; Lorans (ed.), *Le cheval au Moyen Âge*.

15 Andenmatten/Paravicini Bagliani/Pibiri (eds.), *Le cheval dans la culture médiévale*.

16 The expression is Buffon's, in his *Histoire naturelle*, p. 174.

17 Besides the colloquium of Louvain-la-Neuve (Doyen/Van den Abeele [eds.], *Chevaux, chiens, faucons*) which also concerned hunting, there is the colloquium of Abu Dhabi in November 2015 (the publication of the proceedings are currently underway).

18 On camelids, see recent work by Ricciardetto, "Le marquage et les soins vétérinaires appliqués aux camélidés."

almost non-existent, which explains, at least in part, its undeveloped state in modern studies.

Interactions between men and animals have never ceased to multiply and diversify. Following the domestication of certain species, men also began to develop appropriate care to preserve their health as well as to restore it. The increasing number of recipes and prescriptions for the same illness within several successive remedies betray a certain anxiety for the fate of the animal. Men were trying to cure or prevent illnesses, using all the means available to them.[19]

The veterinarian, however, faced one sizeable obstacle: the lack of information in making an accurate diagnosis. This was remarked upon several times by ancient authors, both Latin and Greek. One of the major difficulties concerned diagnosis, because the treatment of animals had to be determined without the benefit of the information usually provided by a patient to his doctor. Vegetius (late fourth century CE) stressed how much easier it was for a physician to assess a human patient's illness since he was able to indicate where it hurt or describe the pain. A veterinarian, however, was confronted with a dumb animal, that could never indicate the source of its suffering.[20] Similarly, for Hierocles (second half of the fourth century CE) identifying symptoms was far easier in human medicine than it was with animal medicine. He wrote on this subject in one of the prologues to his hippiatric treatise that the best physicians note in advance certain signs or symptoms by means of which one can identify each disease. According to him, it is indispensable to use this predictive mode in horse medicine. Indeed, in the case of humans, thanks to the natural faculty of speech, they can indicate their illness, but those who care for them still need to conduct examinations based on their symptoms. But the comprehension of signs learned through experience is certainly far more important when dealing with creatures who are incapable of describing their symptoms.[21]

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19 On ancient and medieval veterinary medicine, see, among others, Leclainche, *Histoire illustrée de la médecine vétérinaire*; Poulet/Sournia/Martiny, *Histoire de la Médecine*, esp. t. 2, pp. 139–87; Karasszon, *A concise history of veterinary medicine*; Dunlop/Williams, *Veterinary medicine*; Tsaknakis, *Ιστορία της ελληνικής κτηνιατρικής*.

20 *Mulomedicina, Praef.* I.7, ed. Lommatzsch. On Vegetius' prologues, see also Zaffagno, "I 'prologi' della 'Mulomedicina' di Publio Vegezio Renato"; Viré, "Les préfaces de la 'Mulomedicina' de Végèce."

21 Ὁρῶν δὲ τοὺς δοκιμωτάτους τῶν ἰατρῶν σημεῖα προλέγοντάς τινα, δι' ὧν ἕκαστον πάθος ἐπιγνώσεταί τις συμπτωμάτων, ἀναγκαιότατον εἶναι νομίζω τοῦτον ἐπὶ τῆς τῶν ἵππων ἰατρικῆς τῆς προμηνύσεως παραλαμβάνειν τὸν τρόπον. εἰ γὰρ τῶν ἀνθρώπων τῇ κατὰ φύσιν ἐξουσίᾳ τοῦ λόγου δυναμένων παραστῆσαι τὸ λυποῦν οὐδὲν ἧττον τῆς ἀπὸ τῶν σημείων τοῖς ἰατρεύουσιν

This additional problem, typical of veterinarian diagnosis was used to criticise openly the Methodics. Thus, Celsus (first century CE) compared the Methodics to 'those who care for small and large livestock,' who, 'unable to learn from animals without speech that which is particular to each individual, confine their observations to general features.' (*De Arte medica*, *Praef.*, 65, ed. Fr. Marx). In Celsus's view, this situation accounts for why veterinarians are included among the Methodics who treat symptoms with remedies which have been proven to be effective, without really seeking to isolate and differentiate the causes of the disease. This kind of criticism, when it does not come from veterinary doctors themselves, is aimed at belittling the practices of the members of the Methodic school of Medicine.[22] However, these attacks, as exemplified by the views of Vegetius at the beginning of his treatise on veterinary medicine, demonstrate also the lack of consideration of several ancient medical authors for veterinary medicine: *sicut enim animalia post hominem, ita ars ueterinaria post medicinam secunda est* (*Mulomedicina, Prol.*, 1, ed. Lommatzsch). From their perspective, the attempt to develop a rational and serious veterinary medicine is impossible.[23]

Although authors insist on the need for veterinarians to seek out the causes of diseases (e.g. Vegetius, *Mulomedicina, Prol.*, 3.15, ed. Lommatzsch), it is obvious from reading veterinary treatises that the etiology and pathogeny of several diseases are underdeveloped despite an often careful description of pathological symptoms. Even if a veterinarian knew the cause of most common ailments, as soon as a disease became more complex, he was very soon at a loss. When confronted with diseases, the causes of which they could not

ἐδέησεν ἐπισκέψεως, πολὺ δήπου μᾶλλον δεῖ τῆς τῶν διδασκομένων γνωρισμάτων καταλήψεως ἐπὶ τῶν οὐ δυναμένων τὸ συμβὰν διελθεῖν. ἵν' οὖν ἀπὸ τῶν μεγίστων ἀρξώμεθα, *Corpus Hippiatricorum Graecorum*, t. 1. *Hippiatrica Berolinensia*, 1.14, ed. Oder/Hoppe.

22 Galen called the Methodics 'methodless.' They are notorious for maintaining that a brief six months training period was all that was necessary in order to begin the practice of medicine. The main founder of the *Methodic school of medicine* was Asclepiades.

23 In contrast to what one can find in several books on the history of medicine, this was not the opinion of the author of *De articulis* (chap. 8, ed. Littré, pp. 95–101) of the *Corpus Hippocraticum*. In a famous comparison between frail men, who suffer from dislocated joints, and emaciated oxen at the end of the winter, who also often dislocate their thighs, he does not look down on physicians who care for the health of domesticated animals. When he wonders about the common sense of making such a comparison, placing human and veterinary medicine on an equal footing, he believes it is justified (ed. *ibidem*, pp. 96–97).

identify, especially in the case of pathologies with no external symptoms, classical and medieval veterinarians could only offer an empirical treatment.[24]

In general, animals were helped to overcome most ailments with rest, adding filler to a well-padded and clean litter, and ensuring a balanced diet. Besides medical and/or food diets, Greek veterinarians prescribed preventive potions for suffering animals, using different ingredients according to different times of the year. These were administered in advance to prevent the onset of seasonal diseases. When a disease manifested itself unexpectedly, it was treated with a combination of diet, bleeding and purging to arrest its development and avoid further complications.

For the treatment of intestinal diseases, diet was paramount, but veterinarians also knew how to prepare laxative potions by macerating various plants. Suppositories were made with fatty substances. Wounds were often coated with unguents and carers waited until they had healed after a period of rest in the stable or barn. Then the animals were slowly re-introduced to their normal activities, with short walks and sometimes even swimming in pools. Various medicinal plants were used in the composition of drops applied to swollen eyes. In terms of tonics, people did not hesitate to make animals, even horses, drink wine, either neat, or diluted with water.

Remedies were often accompanied by superstitious practices; sometimes people only resorted to healers, magic and witchcraft.[25] In both the city and the countryside, where most people believed that diseases had a demonic origin, physicians and bonesetters competed to secure patients. During the Middle-Ages, people turned to official religion, sometimes even to its more mystical aspects. It is in this context, to secure healing, Christian formulae, such as

24 However, to be fair one should also point out that several diseases were described very precisely. E.g. the explanation on glanders, the virulent and contagious disease transmitted from solipeds to men. It is a bacterial infection caused by the Maleomyces mallei species, that causes lesions of the skin (dermatitis), nasal mucous membranes and lungs among equine species. It is characterized by an engorgement of the conglobal glands, because of the alteration of the pituitary membrane and the flow of a mucous material through the nostrils; it is named after this last symptom. Greek veterinarians gave fairly precise descriptions of this disease. They could identify it and treat it appropriately. Among Greek veterinarians, Apsyrtus, followed by Hierocles, distinguished four kinds of glanders, while Theomnestus only described two: dry and wet. This same author differentiated within wet glanders the non-fetid (ἄνοσμος), from the fetid (δύσοσμος).

25 In particular, on magic in hippiatric treatises, see Björck, *Apsyrtus, Julius Africanus et l'Hippiatrie grecque*; Gitton-Ripoll, "Les pratiques magiques dans le *Traité de médecine vétérinaire*"; Poulle-Drieux, "Savoir soigner les chevaux dans l'Occident latin."

prayers and incantations addressed to saints were developed because they were considered to be the only intercessors with God.[26] In general, there has always been a certain confusion in Greece, in Rome or in Byzantium between the efficiency of rational medicine (human or veterinary) and that of magical medicine. One example is Julius Africanus (third century CE), who gives instructions for rational medical treatments, and also for healing and protection amulets (*Cesti*, I.10; I.8; I.11; III.35, ed. Viellefond). Even famed physicians like Alexander of Tralles (*c.* 525–*c.* 605 CE) did not hesitate to approve the use of amulets and other folkloric practices for the well-being of his patients (!).[27] In veterinary texts, we often come across this combination of rational and irrational medicine, which tends to show that for several ancient and medieval authors the separation between the two approaches was rather tenuous. In *Mulomedicina Chironis* (ed. Oder, § 205), for example, incantations and other magical practices used by contemporary veterinarians is criticised, but he also resorted to magical remedies (*ibidem*, § 497, 952, 974).[28] However, other authors unambiguously opposed magical remedies. Vegetius for example (*Mulomedicina*, I.39.2, ed. Lommatzsch) was firmly opposed to incantations and other magical practices used by veterinarians of his time.[29]

Fortunately, because of the recognised success of its operations, ancient veterinary surgery sometimes redeemed the shortcomings of general medicine.[30] In the field of surgical pathology, according to A. Senet, ancient animal doctors knew how to dress wounds properly and regularly renewed fracture dressings

26 L. Thorndike notes the following passage: "If a horse is elf-shot, then take the knife of which the haft is horn of a fallow ox, and on which are three brass nails. Then write upon the horse's forehead Christ's mark, and on each of the limbs which thou may feel at. Then take the left ear; prick a hole in it in silence. This thou shalt do; then take a yerd, strike the horse on the back, then it will be whole. And write upon the horn of the knife these words, *Benedicite omnia opera domini dominum*. Be the elf what it may, this is mighty for him to amends" (Thorndike, *A history of magic*, t. 1, p. 722). Greek hippiatric texts include similar passages (see Björck, *Apsyrtus, Julius Africanus et l'Hippiatrie grecque*, pp. 60, 62, 67 and 70). R. Heim edited 245 Greek and Latin magical incantations (Heim, *Incantamenta magica graeca latina*). On magic and its transmission, see most recently Dasen/Spieser (eds.), *Les savoirs magiques*.

27 The famous physician, after a long demonstration on epilepsy and how to treat it, indicates 'for those who wish it' a few anti-epileptic natural remedies and amulets (Alexander of Tralles, *Therapeutica*, ed. Puschman, t. 1, pp. 557–59 [*Φυσικά πρὸς ἐπιληπτικούς*]).

28 Most scholars date this treatise to the fourth century.

29 Vegetius wrote his treatise at the end of the fourth century.

30 This point of view is shared by many other historians of ancient veterinary medicine (see for ex. Dunlop/Williams, *Veterinary medicine*, pp. 178–84; Tsaknakis, *Ιστορία της ελληνικής κτηνιατρικής*, pp. 165–74).

to hold the bone abutments in contact with brackets. They knew how to make sutures to close a gaping wound, and how to reposition a dislocated joint. Finally, they knew all the usual obstetrical manoeuvres to deliver a baby and ensure its survival in the best condition. Techniques of 'minor surgery' were often practiced: punctures were made to evacuate fluid effusion in the abdomen during ascites (dropsy); they were able to reposition a displaced patella, a vagina could be retracted as well as a prolapsed uterus, they cauterized wounds to ensure asepsis or haemostasis (to stop bleeding). They knew the technique of 'the firing of tendons,' and much as it is done today, how to do so using punctiform deep burns or rays; they practiced bleeding, with the lancet, by attacking all the superficial veins.[31]

Besides obvious difficulties, veterinary medicine developed gradually, and its evolution is part of a long tradition which was inherited from the Greeks, Romans and later the Byzantines to which they sometimes each contributed and enriched in their own way. However, the contribution of the Byzantines is often underestimated, sometimes utterly ignored. Yet, as we will see, several veterinarian hippiatric treatises date from the fourth century and particularly from the end of the first half of that century. In other words, if we follow the conventional chronology of the constitution of the Byzantine empire, they belong to the Byzantine tradition.

Furthermore, at least one of these hippiatric texts was translated into Latin before the end of the fourth century and another in Arabic in the ninth century (see below, n. 72) and two Byzantine reworkings of some of these hippiatric texts were translated in the late Middle Ages into Latin, Italian and the Sicilian dialect and which influenced the work of other veterinarians in the Arab and Western worlds.[32] We should also mention that an eighth-century Arabic author refers to Byzantine texts devoted to raptors (see below, n. 92). Let us not forget that certain late Byzantine texts, like the works on diseases of hunting dogs and raptors by Demetrius Pepagomenos, were highly sought after by the humanists of the Renaissance.[33] From an early period the latter translated and edited a vast number of Byzantine writings on veterinary medicine.[34]

31 Senet, *Histoire de la médecine vétérinaire*, pp. 33–34.

32 E.g. Jordanus Rufus, Pietro de' Crescenzi, Laurenzo Rusio, Johan Alvares de Salamiellas, Guillaume de Villiers and Manuel Díaz de Calatayud.

33 See Lazaris, "Antoine Éparque et le commerce des manuscrits grecs de fauconnerie."

34 See among others Ruel, *Veterinariae medicinae libri duo*; Grynaeus, *Τῶν ἱππιατρικῶν βιβλία δύω*; Brassicanus, *De re rustica*; Rigault, *Ἱερακοσόφιον. Rei accipitrariae scriptores nunc primum editi*.

Thus, the Byzantine contribution to the development of veterinarian medicine was far more important than modern historiography would seem to suggest.

Indeed, in the field of the history of science this picture of a generally stagnant Byzantine civilisation is rooted in a wider vision of the Middle Ages which has lasted far too long and is unfortunately still deeply entrenched in our culture. This period of history is almost entirely obfuscated by the great shadow cast by antiquity and the Renaissance. The very notion of the Middle-Ages, which appeared a few centuries ago to identify the entire period from the end of classical antiquity to the beginning of the Renaissance, involved from the outset a pejorative notion. No less than a collapse and a break in the development of European cultural history. This connotation has endured to this day, at least in certain circles. Is 'medieval' not still associated with certain states of backwardness or lack of culture? 'Medieval' is close to being synonymous with anything that is obscure and reactionary. The adjective 'Byzantine' has shared a similar fate.

After these introductory remarks and warnings against hasty criticisms, this contribution will seek to take stock of the Greek texts that are explicitly devoted to veterinary medicine. Let us mention from the outset that all these works are chronologically recent and none predate 'our era.' Moreover, mentions of 'veterinary physicians' in Greek and Latin are hardly older.

## 1 Ancient Terms Designating the Veterinarian

The first clear reference to this profession in classical literature is found in Varro's treatise on agriculture, completed in 37 BCE where he speaks about ἱππιατροί or *medici pecorum.*[35] As for the word *veterinarius*, it is used for the first time CE in Columelle's work in the first century.[36] In his *De re militari*,

35 More precisely, Varro differentiates between two kinds of diseases in animals. On the one hand, those which, as well as human diseases, require a physician's cares. On the other hand, those whose healing exclusively requires the care of a *pastor diligens*. The latter must be instructed and possess a manual describing the remedies for the diseases which can be treated without resorting to a physician. Varron explains that, for horses, the symptoms of the diseases and the kinds of treatments are so numerous that this *pastor* must be able to draw on written information. He then goes on to say that in Greece, the animal doctors (*medici pecorum*) are generally called ἱππιατροί (*De medicina uel plurima sunt in equis et signa morborum et genera curationum, quae pastorem scripta habere oportet. Itaque ab hoc in Graecia potissimum medici pecorum ἱππιατροί appellati*, Varro, *Res rusticae*, II.7.16, ed. Guiraud).

36 This term designates here an expert in the treatment of animal diseases, who was not yet clearly differentiated from the pastor (*Solent etiam fastidia ciborum afferre vitiosa*

Taruttienus Paternus, a prefect of the praetorium under Marcus Aurelius, later sentenced to *damnatio memoriae* by Commodus,[37] mentions the *veterinarii* among the different occupations exempt from public offices (*Digesta Iustiniani Augusti*, L.6.7 [6], ed. Krueger/Mommsen). Otherwise, the term *mulomedicus* appeared in *Diocletian's Edict on Maximum Prices* (*Edictum de pretiis rerum venalium*, 7.20, ed. Lauffer)[38] and in Vegetius' veterinary treatise, in which the author makes a difference between *mulomedicus* and *medicus* (*Mulomedicina, Prol.* 6, ed. Lommatzsch).[39]

Literary testimonies consist of scattered fragments and rare references up to late antiquity. It was only at this time that the term hippiatrician started to appear regularly in documents.[40] M.-H. Marganne has published a list of 17 papyri offering information on veterinary medicine and on the status of hippiatricians.[41] Most of them are payslips, receipts, accounts, payment orders, IOUs, bills of sale, together with various lists as well as some letters.[42] Two of these papyri date back to the third century BCE, one from the second century CE, one from the third century, two between the third and the fourth, six from the fourth, one from between the fourth and the fifth, one from between the

*incrementa linguae, quas ranas veterinarii vocant; Ovem pulmonariam similiter ut suem curari convenit, inserta per auriculam, quam veterinarii consiliginem vocant* […]; *Nam et arator reperiatur aliquis bonus* […] *tum etiam veterinarius et probus pastor* […], Columella, *De re rustica*, VI.8.1; VII.5.14; XI.1.12, ed. Forster/Heffner).

37 We know this Taruttienus Paternus from literary sources, which only allow for a partial reconstruction of his *curriculum*. His military treatise (*De re militari libri iv*) inspired Arrius Menander (see Pflaum, *Les carrières procuratoriennes équestres*, pp. 420–22; Absil, *Les préfets du prétoire d'Auguste*, pp. 182–83; Herzog/Schmidt, *Nouvelle histoire de la littérature latine*, pp. 151–53).

38 This word has here, as that of ἱππιατρός, a wider acceptation than the one suggested by its etymology, so it can be applied to all large-sized farm animals.

39 As noted by Dunlop/Williams, *Veterinary medicine*, p. 157 (fig. 140): "there is some confusion over the use of this term [*mulomedicus*]; it was used to describe both horse doctors and slaves who had regained their freedom."

40 On the terms used, see for example Fischer, "Ancient Veterinary Medicine," pp. 191–93; Adams, "The Origin and Meaning of Lat. *Veterinus*"; Adams, *Pelagonius and latin veterinary terminology*, pp. 51–65. See also Nanetti, "Ἱππιατροί" who studies several Greek and Latin inscriptions and papyri.

41 Marganne, "Témoignages papyrologiques sur la médecine vétérinaire," pp. 155–56. As she points out, the deciphering of the of the word ἱπ⟨π⟩ιατρός in P.Gen I 42 (line 35) is rejected henceforth (on this papyrus, see also Schubert/Jornot, *Les papyrus de Genève*, pp. 170–73).

42 On these letters, see recent work by Ricciardetto, "Témoignages sur l'art vétérinaire dans les lettres conservées sur papyrus," pp. 93–106.

fifth and the sixth, three from the sixth and, finally, one from the seventh century. Among these documents, particularly notable is the reference to a tax paid to a veterinary physician (ἱ̣π̣π̣ιατρικόν)[43] in *P. Hib.* 1.45 (= Trismegistos 8196), which is dated between January 25 and February 23, 257 CE.[44] Mention should also be made of the substantive ὀνοϊατρός in *P. Laur. inv.* III/376, v°, l. 3, which dates from the fourth century CE. This is an inventory of payments to various people, among which one is intended for a donkey physician.[45] A new element should be added to that list:[46] the papyrus *SB* 14. 12059 (= Trismegistos 30109) of the third/fourth century CE, which includes a series of occupations, among which is that of hippiatrician (ἱ̣π̣π̣ίατρ[οι]).[47] It should be stressed that the profession occurred in documentation on a regular basis from this period. The change compared with the previous centuries can be seen in the light of the development of Latin as well as Greek hippiatric literature.

The term *mulomedicus* has, just like ἱππιατρός, a broader accepted meaning than is suggested by its etymology and applies to all large animals. The distinction between physician and veterinarian, veterinarian and horse manager in the agricultural field, in the army or in the post, was not clearly defined before the third century CE. Not only were there no clearly established criteria to define the veterinarian profession, but it is quite probable that there were no veterinarian schools. It is indeed highly likely that future veterinarians in antiquity were trained in human medicine[48] before they specialised with a master, or learned veterinary medicine on the job.[49] Human medicine offered a model of organization into which veterinarians were able to integrate their own knowledge. This first observation is reinforced by the fact that several diseases are common to both sciences and often treated in the same way. As Kl.-D. Fischer writes, in antiquity, far more than today, veterinary medicine

43 This is, in all likelihood, a tax established on the same model as the ἰατρικόν (see Nanetti, "To iatrikon"; Lippi, "Breve nota").

44 Text available online: <http://www.papyri.info/ddbdp/p.hib;1;45/>.

45 Marganne, "Témoignages papyrologiques sur la médecine vétérinaire," p. 153.

46 I am currently working on a few other unpublished documents relating to the profession of hippiatricians.

47 See Sijpesteijn/Klaas, "Greek Texts in the Possession of the Amsterdam University Library," p. 105 (n° 5). Text available online: <http://www.papyri.info/ddbdp/sb;14;12059/>.

48 On medical teaching, see chapters 2 and 10 of this volume.

49 On hippiatric teaching, see Cam/Poulle-Drieux/Vallat, "Questions d'anatomie chez Végèce"; Lazaris, "Learning and memorising hippiatric knowledge."

looked to human medicine, seeking to transfer and use its knowledge and experience.[50]

## 2 Veterinary Texts

As indicated above, the first works devoted entirely to veterinary medicine appeared at the end of the third century CE. Before this time, data relating to veterinary medicine is scattered through treatises on zoology, medicine, zootechny and rural economy. Among our indirect sources, we have Greek texts in hippology and on hunting, like the treatise on horsemanship (Περὶ ἱππικῆς) by Simon of Athens (fifth century BCE). With the exception of a fragment cited in the manuscript Cambridge, Emmanuel College, III. 3. 19 (thirteenth century) and, in a more rudimentary version, in the codex London, British Library, Sloane 745 (thirteenth century) and in Leiden, Bibliotheek der Rijksuniversiteit, Voss. Misc. 40 (seventeenth century) this work is lost. Simon's treatise is said to have been used by Xenophon for his own treatise on the same subject.[51] These two books contain indications concerning the health of horses and dogs and the means to preserve and fortify it. In the texts that make up the *Corpus Hippocraticum*,[52] we find little information on animals and their diseases. In the *De articulis* for example we read (chap. 8, ed. Littré, pp. 95–101) a long study on the problem of the dislocation of the thigh among oxen. These are mainly ploughing oxen at the end of the winter, when the animal was feebler and more vulnerable. The author takes this opportunity to criticise the methodological error of those who try to reposition the dislocation without having studied the nature of the joint. In saying this he is referring to the intervention of non-veterinarians, either livestock breeders or the herdsmen themselves, or healers like magicians and charlatans. In his work Aristotle (384–322 BCE) also evokes several animals and in addition to anatomical data, lifestyle, diet, mating and growth, he also mentions the main diseases like gout, colic, laminitis,

50 Fischer, "L'opération de la cataracte," p. 235.

51 Xenophon at the beginning of his hippological treatise (*De re equestri*, I.1) refers to an author by the name of Simon who had written a treatise on the equestrian art. He mentions him further in his treatise (I.3 and XI.6). There are other references to Simon in Arrianus (*Cynegeticus*, I.5, ed. Roos/Wirth), Pollux (*Onomasticon*, I.190, 198 and 204; II.69, ed. Bethe) as well as in the byzantine lexicon known as the *Suda* (A 4739, *s.v.* Ἄψυρτος [= Κίμων] and T 987, *s.v.* τρίλλη, ed. Adler).

52 Sixty or more treatises are regrouped under Hippocrates' name, although he did not write them all.

glanders or rabies.[53] Aristotle sourced his evidence from the testimonies of breeders, herdsmen and veterinarians.[54] He studied in great detail (*Historia animalium*, VIII.20–26, ed. Balme) the diseases that plagued pigs, dogs, cattle, horses, donkeys, elephants, insects and fish. The latter suffered from excessive flatulence and diarrhoea. They were treated by rubbing their shoulders with salt, oil and warm water. If they suffered from pains in their shoulders, roasted pork meat was applied to provide relief. Aristotle was interested in everything he could learn from veterinarians as he was convinced that humans could be afflicted by almost all the same diseases as those from which animals suffered (*Historia animalium*, VIII.24, 604b 25–27, ed. *ibidem*). However, regardless of his descriptions of diseases, he failed to write a proper treatise on veterinary medicine.

In Book 8 of his *Naturalis historia*, Pliny the Elder (23–79 CE) considers several animals and describes some of their afflictions, like the loss of appetite, epilepsy or rabies. Galen (129–ca. 200 or ca. 216 CE), allows a significant space to indications borrowed from or referring to veterinary medicine, but produces no new elements, except in his description of rabies and in the field of anatomy arising from his dissection of elephants, goats, pigs, sheep or dogs.[55] Finally, among the richest indirect sources, the treatises by Roman agronomists have a special place: Cato (234–149 BCE), Varro (116–27 BCE), Virgil (70–19 BCE), Columella (4–*c.* 70 CE) and Palladius (fifth century CE). The chapters in their respective works (*De agricultura*, *Res rusticae*, *Georgica*, *De re rustica*, *Opus agriculturae*) devoted to breeding livestock and horses include details on the health and hygiene of domesticated animals, in a case by case series of remedies, based either on previous veterinary consultations or personal experience. They also recommend reaching out to a specialist when the circumstances so require.[56]

The *Geoponica* are among the first sources, in Greek, to have preserved large extracts explicitly devoted to veterinary medicine (on this work, see also chapters 8 and 9 of this volume). In this agronomic collection, several chapters are dedicated to animal diseases: oxen, sheep, lambs, bulls, calves, dogs or even horses. The geoponic texts, in their current state, date from the middle of

53 See Stuempfler, *Die Kenntnisse des tierischen Körpers bei Aristoteles*.

54 See Manquat, *Aristote naturaliste*.

55 See Siegel, *Galen's System of Physiology and Medicine*.

56 The second book of Varro's *Res rusticae*, of which three chapters relate to equine animals (II.6–8), only addresses their diseases in passing (II.7.16). Columella (*De re rustica*, VI.27–38) is the first author who discusses their pathology in detail. Book 14 in Palladius' *Opus agriculturae* is inspired for the most part by Columella's books 6 and 8. See also Walker, "Roman Veterinary Medicine."

the tenth century and were 'edited' on the orders of Constantine VII Porphyrogenitus, by an anonymous compilator often identified as Kassianos Bassos. In fact, Bassos' *Eklogai* (Περὶ γεωργίας ἐκλογαί) were recopied almost entirely by this anonymous compiler under Constantine VII, with a few changes here and there and camouflaged by the added προοίμιον.[57] Although there has been a tendency to date Kassianos Bassos to the tenth century,[58] we now know that he lived in the sixth century.[59] Bassos' compilation is based in turn on the work of Vindanius Anatolius of Berytus[60] (fourth century CE), mentioned in Photios's *Bibliotheca* (cod. 163, ed. Henry).

Each of the twenty books of the *Geoponica* is divided into several numbered chapters, with a table of contents and almost always begins with an introductory sentence. Each chapter bears a title, usually followed—with few exceptions—by the name of the supposed author of the chapter. The first book, in contrast with all nineteen others, begins with two propositions, that announce in the first person the book's main theme: I have compiled this work by collecting the writings of several early authors on farming, the care of trees and crops, and other useful subjects. Then follows a list of nineteen authors, presented as the sources of the work, but this catalogue does not list all the people whose name is attached to the titles of the chapters.[61] The text continues, always in the first person: I decided it was necessary and appropriate to prefix to the whole work the elementary facts that those taking up farming need to know in advance: this first book therefore includes signs of good and bad weather, the

57 See Georgoudi, *Des chevaux et des bœufs*, pp. 15–72; Kanelopoulos, "À propos des 'Géoponiques' grecs." For an analysis, based on this προοίμιον, of a potential contribution by Constantine VII himself, see Koutava-Delivoria, "La contribution de Constantin Porphyrogénète." See also Amato, "Costantino Porfirogenito ha realmente contribuito alla redazione dei *Geoponica*?"

58 For a long period of time, philologists and literary historians have had a tendency to attribute a number of little known texts to the cultural renewal spearheaded by Macedonians; among which the *Geoponica* (see Sprengel, *Historia Rei Herbariae*, t. 1, pp. 215–16). We now know that this period did not witness the arrival of new texts, but instead, a massive influx of anthologies, ἐκλογαί, extracts, summaries, or compilations.

59 In his important study which remains to this day a reference in the field, E. Oder, places Bassos' Περὶ γεωργίας ἐκλογαί in the same context as the medical *Sammelwerke* of Aëtius of Amida and Alexander of Tralles and dates this compilator from the sixth century (Oder, "Beiträge zur Geschichte der Landwirtschaft bei den Griechen"). On the *Geoponica* and the Περὶ γεωργίας ἐκλογαί by Kassianos Bassos, see also Lelli, *L'agricoltura antica*.

60 On this author, see Ito, "On Anatolios in the *Geoponika*."

61 For the full list, see Andrew, *Geoponika farm work*, pp. 36–49.

rising and setting of major stars, and the effects of the natural environment (*Prol.* § 7, ed. Beck).

The *Geoponica* include passages from various authors, many of whom would have otherwise remained unknown. One of the oldest is the Carthaginian Mago (third century BCE), who wrote a manual of agronomy which was translated into Greek and Latin and had a profound impact on Roman agronomists. Most of the quoted authors belong to the early Byzantine era and lived between the end of the third and the beginning of the fifth century CE. Among these authors, Apsyrtus of Clazomenae (second quarter of the fourth century), Hierocles (second half of the fourth century), Hippocrates [the hippiatrician] (second quarter of the fourth century), Pelagonius (beginning of the second half of the fourth century) and Theomnestus (end of the first half of the fourth century), are well-known for their hippiatric texts.

We also find large extracts, from other authors than those above, in another work: the *Corpus hippiatricorum Graecorum* (or *Hippiatrica*, ed. Oder/Hoppe, 1924 and 1927). As its title indicates, it is devoted almost exclusively to horse diseases[62] based on the writings of several Greek and Latin authors. The reason why a specifically hippiatric literary production emerged is probably because of the importance of this animal in the army, from the late Roman period to the early Byzantine era. Indeed, the intensive use of the horse in late antiquity is closely linked to Roman military strategic and tactical efforts, and the search for a greater mobility after a number of severe defeats endured in the first centuries CE.[63]

In terms of military history, this period is considered to be significant, because it is marked by the transition from Roman foot soldiers to fighting on

62 In fact, we find a few chapters focussing on other animals like the ox and the donkey.

63 There is a connection that went unnoticed in studies on the subject and that reinforces this point: the almost contemporary development of the Athenian cavalry by Pericles—which brought the body instituted by Solon to the size of a thousand men—and the appearance of the first written equestrian treatise in Greek language, the περὶ ἱππικῆς by Simon of Athens (see above). There is an intensification of equine literary production at two moments of history where the horse takes on a more decisive importance in the army: during the golden age of the Athenian city, between the Persian wars and the Peloponnesian war, then in late antiquity. And these works are not anonymous. Their authors were famed throughout antiquity. On cavalry in the Greco-Roman and Byzantine worlds, see (in chronological order): Vigneron, *Le Cheval dans l'antiquité gréco-romaine*; Hyland, Equus; Hyland, *The medieval warhorse*, pp. 18–53; Hyland, *The Horse in the Middle Ages*; McCall, *The cavalry of the Roman Republic*; Hyland, *The horse in the ancient world*; Stephenson/Dixon, *Roman Cavalry Equipment*; Haldon, *Byzantine warfare*; McGeer, *Sowing the dragon's teeth*; Rance "Cavalry"; Lazaris/Cristina, "Le cheval de guerre."

horseback as practiced by the Byzantines. Yet, this intensive use of the horse in the army could not have emerged without the development of veterinary medicine to provide the necessary care for this fragile animal. It is mainly for this reason that several hippiatric texts were written in the first place.[64] Three Latin works must be mentioned: the *Ars veterinaria* by Pelagonius (initially written in the form of letters which were preserved in a reworked edition attesting to the existence of different recensions), the *Mulomedicina Chironis* (compilation in ten books) and the *Mulomedicina* by Vegetius. On the Greek side, we have extensive excepts from earlier works preserved in the *Corpus hippiatricorum Graecorum* (or *Hippiatrica*).[65]

This work is mainly composed of fragments of texts from seven authors. In addition to the five authors previously mentioned (Apsyrtus of Clazomenae, Hierocles, Hippocrates [the hippiatrician], Pelagonius and Theomnestus), we can add Anatolius of Berytus (fourth century CE) and Eumelus (late third or early fourth century CE). The texts attributed to these seven authors are completed by other treatises,[66] but from a quantitative point of view, they are less important and not necessarily present in every recension of the *Corpus hippiatricorum Graecorum*.[67]

We can attribute the activity of these authors to a period extending from the end of the third to the end of the fourth centuries (see also above for the dates for each author).[68] Texts from this period are characterized by their authors'

64 On the Byzantine army in general, see chapter 12 of this volume.

65 In addition to the bibliography mentioned above, the reader might wish to read specialised studies such as: Rieck, "Zur Pathologie der Pferdeseuchen im Mittelalter"; Walker, "Malleus and podagra"; Théodoridès, "Rabies in Byzantine Medicine"; Bourdy, "L'ophtalmologie équine"; Cam, "Proposition de lecture."

66 Tiberius (part of the group of agricultural writers and his work included treatments for both horses and cows); Julius Africanus (many excerpts from his work are found in one of the recensions of the *Corpus hippiatricorum graecorum*); Προγνώσεις καὶ ἰάσεις (this anonymous work is notable for its reliance upon cautery and its avoidance of irrational remedies).

67 In total seventeen authors are mentioned, but aside from the seven authors already mentioned, the names of the authors are only linked to a few chapters every time. On the *Corpus hippiatricorum Graecorum*, see McCabe, *A Byzantine Encyclopaedia of Horse Medicine*.

68 Since G. Björck's study (*Apsyrtus, Julius Africanus et l'Hippiatrie grecque*, pp. 7–12), the chronology of Apsyrtus has been hotly debated. His period of activity is all the more important because it is the basis on which we calculate the period of activity of most of the authors in the *Corpus hippiatricorum graecorum*. I have reassessed the dating of Apsyrtus (second quarter of the fourth century) which G. Björck placed between 150 and

need to explain to their audience the reasoning which lead them to recommend this or that treatment. As noted by V. Gitton-Ripoll,[69] authors such as Pelagonius and Vegetius have endeavoured to demonstrate the validity of their art, justifying nosology, etiology and therapy relying as much on argumentative logic as on other rhetorical techniques. This same need is obvious in the texts of the Greek authors listed above. In contrast, previous agronomic treatises were almost exclusively aimed to practical use: a disease corresponded to a list of remedies without any further justification. At the end of the third century the situation changed: veterinary medicine was no longer part of agronomy, but claimed to be a branch of medicine, to which it borrowed its logical concerns. Indeed, in both Greek and Latin preserved hippiatric texts, authors strive to make a diagnosis,[70] to seek to know the causes of the diseases and finally to offer an appropriate treatment.

Other than that of Pelagonius, the original works of these authors have not been preserved. Most of his treatise, originally written in Latin, is preserved. Let us mention as well the Arabic translation of Theomnestus' work which is more complete than the preserved Greek text in the *Corpus hippiatricorum graecorum*. 72 chapters are preserved in the *Hippiatrica* and 94 in the Arab translation. Furthermore, the introduction of the treatise is only preserved in Arabic. This translation is preserved in two manuscripts.[71] In both codex the translation is attributed in a colophon to Ḥunayn ibn Isḥāq (808–873). The translation was used by Ibn Akhi Hizam in the ninth century.[72] We should also note that Apsyrtus' text was apparently translated into Latin at an early date because Vegetius, who refers to it, mentions that he only use Latin authors (*Mulomedicina, Prol.*, 1.6 ed. Lommatzsch).

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250 CE (Lazaris, "Essor de la production littéraire hippiatrique et le développement de la cavalerie"). Yet, dating, here is a secondary issue, because these Greek and Latin texts—as late as they may be—disseminate the accumulated knowledge of a long tradition made of the combination of the experience of breeders, herdsmen and the knowledge of anonymous (or not) practitioners of veterinary medicine.

69 Gitton-Ripoll, "L'art de la démonstration chez les vétérinaires latins," pp. 334, 335.

70 According to the hippiatric texts, the diagnosis can only be established from the signs (σημεῖον, προγνωστικόν, σύμπτωμα …) which point to a disease, since the animal, as we have seen previously can hardly be expected to indicate the source of its suffering to the veterinarian.

71 Istanbul, Köprülü Library, MS 959 and Paris, Bibliothèque nationale de France, ar. 2810.

72 See also Weidenhöfer, "Ninth-century CE Arabian horse medicine. The Kitāb al-furūsīya wa-l-bayṭara of Muḥammad ibn Yaʿqūb ibn aẖī ḥizām al-Ḫuttulī"; Hoyland, "Theomnestus of Nicopolis."

Regarding the production of the *Hippiatrica*, their writings were selected among others, keeping only the extracts considered to be the most significant, and classified by subject to form a coherent whole. This is how the *Recentio prima* (= A) of the *Corpus hippiatricorum Graecorum*[73] was born. These texts were probably assembled at the very beginning of the sixth century.[74] *The Recentio prima* was never preserved. To this date, we only know four recensions (= M, B, D and RV 3, a–b), to which can been added two 'new' works from the *Corpus hippiatricorum Graecorum*. These are the *Epitome*,[75] which dates roughly to the same period as the *Recentio prima* and Hierocles' recomposed work, from a later date, and which I call for convenience 'Hierocles recomposed.'

The text of the *Epitome* is known in eleven copies[76] of five recensions (= HIG, S, QZF, Jj and RV 2)[77] which have reached us through nine manuscripts, among which two are illustrated.[78] The 'Hierocles recomposed' is preserved in four manuscripts and divided in two families (= I, [X][79] and RV 1).[80]

73 Beside the texts by Greek authors, the *Corpus hippiatricorum Graecorum* has also preserved the Greek translation of the work of Pelagonius. On this Latin author, see Adams, "Pelagonius, Eumelus and a lost Latin Veterinary Writer"; Adams, *Pelagonius and latin veterinary terminology*; Gitton-Ripoll, "Contribution de la prosopographie à une possible datation de l'*Ars veterinaria*."

74 Just like the *Geoponica*, the production of the *Hippiatrica* had for a long time been placed during the reign of Constantine VII. K. Krumbacher in the first edition of his work on the history of Byzantine literature (1891) had even suggested that Hierocles had written these two works at the time of the emperor Constantin VII. His idea had the advantage of explaining the many common passages between the *Geoponica* and the *Hippiatrica* (see Krumbacher, *Geschichte der byzantinischen Litteratur*, pp. 67–68). See also Lazaris, *Art et science vétérinaire à Byzance*, pp. 31–35.

75 On this text, see Doyen-Higuet, *L'Épitomé de la Collection d'hippiatrie grecque*; Lazaris, *Art et science vétérinaire à Byzance*.

76 Until recently we only knew 10 copies preserved in eight manuscripts, but I have just discovered a ninth manuscript (= j) for which I will soon publish a codicological notice.

77 See Lazaris, *Art et science vétérinaire à Byzance*, pp. 9–35 and 135.

78 Leiden, Bibliotheek der Rijksuniversiteit, Voss. gr. Q. 50, middle of the fourteenth century and Paris, Bibliothèque nationale de France, gr. 2244, fol. 1–74 and 90–195, late fourteenth century. On these manuscripts and their illustration, see Lazaris, *Art et science vétérinaire à Byzance*, pp. 41–61). It is not the nature of the content that prevented its illustration but probably the intended readership of these manuscripts.

79 The Paris, Bibliothèque nationale de France, gr. 2419, fol. 159r–v (= [X]) only contains Hierocles' introduction to his second book. His siglum is between brackets to indicate that philologists have not yet confirmed the historical accuracy of this piece of evidence.

80 On the various manuscripts, see Lazaris, *Art et science vétérinaire à Byzance*, pp. 150–51.

Indeed, at first, the *Corpus hippiatricorum Graecorum* was epitomized.[81] This process resulted in the creation of a summarised text, an *Epitome*, according to the title in one of the manuscripts, which reproduced this text: the *Vatican, Biblioteca Apostolica Vaticana, Pal. gr.* 365, f. 204r: Ἰατρικὸν ἐν ἐπιτόμῳ ἄριστον περὶ ἵππων κατ' ἐκλογὴν ἔχον κεφάλαια διάφορα ('excellent medical epitome on horses, containing different chapters selected').[82] Thereafter, we witness the opposite phenomenon which had prevailed in the production of the *Corpus hippiatricorum Graecorum*. While the latter was based on the use of extracts borrowed from the original writings of several hippiatrists (see above), the 'Hierocles recomposed' is based on another principle: extracts attributed to this author from the *Corpus hippiatricorum Graecorum* were selected and compiled in the form of two books as if they had been the original and fully-fledged work of Hierocles.[83]

Therefore, hippiatric medicine caught the interest of the Byzantines for a number of reasons. This interest never wavered throughout the history of the empire, including and especially during the successive cultural revivals.[84] This interest began when the first texts by most of the authors found in the *Hippiatrica*, started to emerge (Apsyrtus, Hierocles, Hippocrates [the hippiatrician],

81 Let us also mention that this *Epitome* includes practical indications, which are not found anywhere in the *Corpus hippiatricorum.* Furthermore, this epitome is not a summary, *stricto sensu*, of the hippiatric collection, but picks up several passages of the latter. The writer(s) of the epitome genuinely sorted the data derived from the *Corpus hippiatricorum*, since everything relating to the field of zootechny and of hippology has been excluded and does not offer, for each topic, the views of various authors. On the abbreviation of texts in Late Antiquity and Byzantium, see for example: van der Eijk, "Principles and Practices of Compilation and Abbreviation"; Inglebert, "Lactance abréviateur de lui-même"; Marjanović-Dušanić/Flusin, *Remanier, métaphraser*; Zucker, "Qu'est-ce qu'épitomiser ?"

82 Yet, this notion of summary does not appear in the titles of all the manuscripts, far from it (see Lazaris, *Art et science vétérinaire à Byzance*, p. 24, n. 80).

83 The reason for choosing Hierocles among the seven authors whose work was the foundation of the constitution of the *Corpus hippiatricorum Graecorum* is unknown. It may because of his general reliability and his eloquence. Ironically, his trustworthiness is due to the fact that Hierocles plagiarised Apsyrtus, one of the most brilliant hippiatrists in antiquity. And regarding his eloquence, it probably came from his real training as a lawyer (in the prologue of the first book of his treatise, he alludes twice to the tribunal), but harbouring a true passion for horses.

84 When we mention 'revivals' we do not mean a 'new beginning'; we are simply adopting this terminology to highlight historical moments in which a significant number of scholars devoted their efforts to the production and study of books and texts, often in the wake of a special increase in educational policies and cultural investments.

Pelagonius, Theomnestus…) and it persisted with the *Recensio prima* (= A) of the *Hippiatrica*, which was probably written in the early sixth century. Thereafter, various recensions emerged all based on the *Recensio prima*, including the very first (= M), which are preserved to this day in the *Corpus hippiatricorum graecorum*, which dates from the beginning of the Madeconian cultural revival.[85]

As for the *Epitome* and the 'Hierocles recomposed,' even if the preserved manuscripts are chronologically late (fourteenth–seventeenth centuries), they were originally produced at a much earlier date.[86] The first work is most likely from the *Recensio prima* of the *Corpus hippiatricorum graecorum*. The composition of the *Epitome* is now fixed around the same period as the *Recensio prima*, quite probably towards the end of the sixth century (under Justinian?).[87] The 'Hierocles recomposed' was composed from two recensions (= B and D) of the *Corpus hippiatricorum* or, more precisely, from the text of an archetype of these recensions.[88] The oldest preserved copy, the Berlin, Deutsche Staatsbibliothek, Phillipps 1538 (gr. 134), from the tenth century, constitutes the *terminus ante quem* of the redaction of the 'Hierocles recomposed.'

The diagram in Fig. 11.1 below summarises the relationships between the major Greek hippiatric works (mentioning preserved manuscripts).

This short overview of the history of hippiatric texts highlights how much the Byzantines (even after the fall of the empire) were fascinated by horses. Thereafter, the systematic copying of manuscripts shows how much they

85 Indeed, the closest recension to the *Corpus hippiatricorum graecorum* dates from before the tenth century, date of the copy of the most ancient hippiatric manuscript known to us (Berlin, Staatsbibliothek zu Berlin [Preußischer Kulturbesitz], Phillipps 1538 [gr. 134]), which contains the text from the second recension (= B).

86 As already mentioned, these two works were very famous in the medieval West through many translations (Latin, Italian, Sicilian dialect, etc.). In addition, these same texts influenced, directly or indirectly, several authors covering a period of about three centuries (thirteenth–fifteenth). See Lazaris, "Contribution à l'étude de l'hippiatrie grecque et de sa transmission à l'Occident (XIIIe–XVe siècles)"; Fischer, "'A horse! a horse! my kingdom for a horse.' Versions of Greek Horse Medicine in Medieval Italy"; Montinaro, "Il 'De medicina equorum' di Giordano Ruffo. Tradizione romanza e spunti lessicali"; Pagano, "Les traités de 'mascalcia' en sicilien médiéval"; Fichera, "Una inedita traduzione del trattato di Ierocle in volgare siciliano."

87 See Lazaris, *Art et science vétérinaire à Byzance*, p. 35. On the circulation of pagan culture under Justinian, see Kaldellis, "The Works and Days of Hesychios the Illoustrios of Miletos."

88 Recension D is very close to B with regards to the sources, its organisation, which suggests that the two recensions were based on a common corpus which I have called *Primitive Corpus B*.

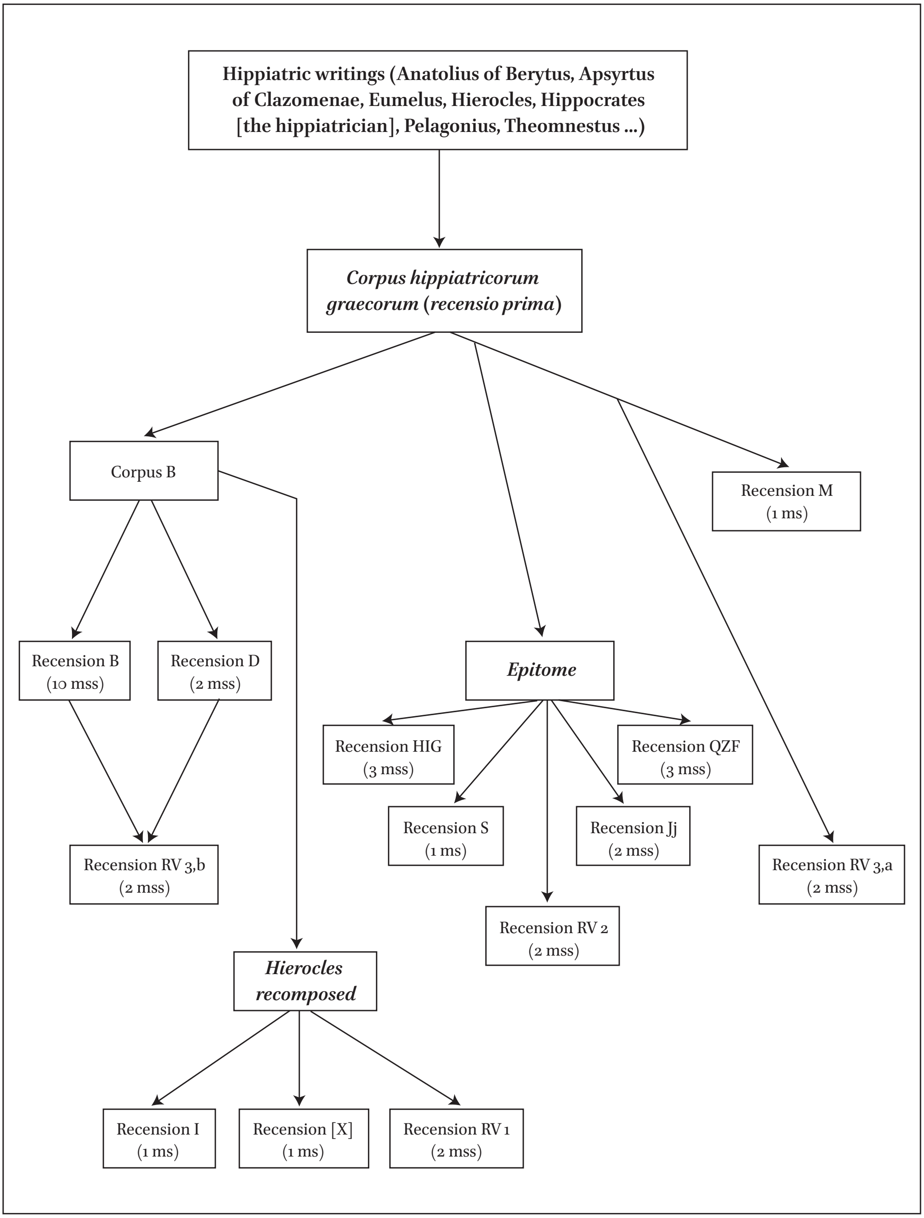



FIGURE 11.1 The major hippiatric treatises

wished to preserve this precious hippiatric knowledge. Indeed, they collected every available piece of knowledge from the Greeks and Romans and other peoples and developed a practical hippiatric science while preserving the knowledge of their forebears. They then transmitted this knowledge to the West either by direct contact or via Arabic translations.[89]

This interest of the Byzantines for some animals and the efforts undertaken to care for them is not only evident from the Geoponica and Hippiatrica, but also in the new literary production on dogs and raptors.[90] Hunting and especially falconry had occupied an important place in Byzantine culture since the eleventh and twelfth centuries and it remained so until the end of the empire.[91]

We have, for example, various treatises devoted to raptors, describing their training, their selection, education, food. Yet, this literature held no interest for the Byzantines before the late Byzantine era. Not only do they appear very late in the textual evidence, but the evidence itself is very slim in comparison with the Latin and Arabic production. Of course, this does not mean that nothing was written in previous centuries. For example, Al-Ġiṭrīf the Syrian, in the eighth century, refers in his work to Byzantine sources.[92] Yet, none of these were preserved and it is likely that these writings only amounted to a few texts and were little known.

The only two Greek texts (Περὶ τῆς τῶν ἱεράκων ἀνατροφῆς τε καὶ θεραπείας and Ἕτερον ὀρνεοσόφιον ἀγροικότερον εἰς ἱέρακα) on this subject date from the very end of the Middle Ages. They are either anonymous or came to us under the name of Demetrius of Constantinople.[93] Demetrius of Constantinople is no other than Demetrius Pepagomenos, a Byzantine scholar who should not be confused with his namesake of the thirteenth century. Our Pepagomenos

89 See Goebel/Heide, "Transmission of Greek and Arabic veterinary literature."

90 On the other hand, data on horse care in the *Sylloge Tacticorum* (§ 65–69, ed. Dain; transl. Chatzelis/Harris) are not *stricto sensu* in the field of veterinary medicine. Rather, these are more akin to tips and practical remedies related to the welfare of these animals in military combat.

91 See Lazaris, "Jagen in Byzanz."

92 See the edition established by Viré/Möller, *Al-Ġiṭrīf ibn Qudama al-Gassani, Traité des oiseaux de vol*, pp. 21–22. See also Viré, "La fauconnerie dans l'Islam médiéval"; Van den Abeele, *Texte et image dans les manuscrits de chasse*, p. 14.

93 More precisely, they were attributed to a certain Demetrius of Constantinople in Paris, Bibliothèque nationale de France, gr. 2323. The other manuscripts that preserve these writings do no mention any author, except Munich, Bayerische Staatsbibliothek, gr. 390 in which a later hand also mentions Demetrius of Constantinople as the author of the treatises on falcons. About this scholar and his period of activity, see Lazaris, "La production nouvelle en médecine vétérinaire."

lived in the fifteenth century[94] and he knew Byzantine scholars like John Chortasmenos, John Bessarion and John Eugenicus, if not in person, at least via an epistolary correspondence.[95]

In these texts, the author is as interested in the training of the raptors as he is in their health. A number of manuscripts which preserved these two treatises have also preserved a third text on cynegetics (Βιβλίον περὶ κυνῶν ἐπιμελείας). It is devoted to hunting dogs, but does not include the author's name.[96] In fact, Demetrius Pepagomenos was also the author of this work.[97] However, it is almost certain that he did not write the second hunting treaty on falcons (Ἕτερον ὀρνεοσόφιον ἀγροικότερον εἰς ἱέρακα). In the Byzantine manuscripts that preserved it, this second treaty on falcons was added to the first to supplement it, without any pretence or any effort to make it look as if it were by the same author.

In Pepagomenos' first treatise on raptors (Περὶ τῆς τῶν ἱεράκων ἀνατροφῆς τε καὶ θεραπείας), the symptomatology is so succinct at times that it is often quite difficult to determine which diseases the author is describing in the 303 chapters of this text.

In the introduction to this work, Pepagomenos emphasizes the importance of medicinal herbs. Even though he also mentions the importance of 'sacred stones' (ἱερῶν λίθων), the main therapy he offers is herbal. The author describes in detail the diseases raptors suffer from and the various treatments. The recipes even include some magical protocols. For the treatment of these 'sacred birds' (ἱερῶν ὀρνίθων, ed. Hercher, p. 335),[98] he describes remedies of which he

94 This Byzantine scholar was located in the thirteenth century by almost all researchers. Although we have found traces of a Demetrius Pepagomenos who lived in the thirteenth century, there is no evidence that justifies the attribution of these works to him. Indeed, the language used in these writings, the absence of manuscripts prior to the fifteenth century and the absolute silence of Byzantine authors who lived since the thirteenth century about these works, are all elements that lead me to think that the author of the hunting texts was the Demetrius Pepagomenos of the fifteenth century.

95 See Lazaris, "La production nouvelle en médecine vétérinaire," pp. 251–52.

96 His treatise was inspired by the text by Arrian of Nicomedia (85–146) on the same subject (on this treatise, see Phillips/Willcock, *Xenophon & Arrian, On Hunting*). The work by Demetrius Pepagomenos includes, after a brief description of dog breeds, recipes to treat them.

97 See Lazaris, "La production nouvelle en médecine vétérinaire."

98 It should also be mentioned that the Greek word for falcon is ἱέραξ (*hierax*) which in everyday language is close to ἱερός (*hieros*), sacred. Finally, let us emphasize that the term ἱέραξ for the periods we are interested in refers almost exclusively to the falcon and not to other small day raptor as mentioned in certain dictionaries.

was made aware through divine inspiration, both in his dreams[99] and through his own research (τὰ μὲν οὖν δι᾽ ὀνείρων αὐτοῦ θεοῦ καθηγεμόνος τυχών, τὰ δὲ διὰ πολλῆς πείρας πολλῷ τῷ χρόνῳ συνεργῷ, ed. Hercher p. 336). He often recommends health-recovery diets.

For example, for the epileptic falcon (Εἰς ἐπιληπτικὸν ἱέρακα) the author, as stated in chapters 60 and 61, recommends a special diet:

60. cook a bat and feed it to him, he will be cured (Ἐὰν ἐπιληπτικὸς ᾖ ὁ ἱέραξ, νυκτερίδα πιάσας ἕψε καὶ δίδου φαγεῖν, καὶ θεραπευθήσεται, ed. Hercher p. 391).

In the next chapter, he recommends another treatment:

61. take a goat's brain, pass it through a gold ring, then feed it to the epileptic falcon and you will be amazed (Ἐγκέφαλον ἐρίφου λαβών, πρῶτον διαβιβάσας εἰς δακτύλιον χρυσοῦν, δὸς φαγεῖν τῷ ἐπιληπτικῷ ἱέρακι, καὶ θαυμάσεις, ed. *ibidem*).

As L. Moulé pointed out, since there is no description of the symptoms, we assume that it is epilepsy, since that is what the Greek term clearly indicates. But it could also be an epileptiform condition caused by the presence of worms in the digestive or respiratory tract.[100]

Both treatises are preserved in 11 manuscripts and date from the fifteenth to the seventeenth century. Three new manuscripts must be added to the list I established in a previous study of Pepagomenos.[101]

The production of these new texts on the diseases of dogs and raptors was surely the result of the huge popularity of dog hunting and falconry in Byzantium from the eleventh and twelfth centuries. Thereafter, the whole activity of hunting gradually changed. Older forms endured, forms involving catching

99 The issue of the 'revelation' of knowledge in dreams is ancient and it is very interesting that Pepagomenos also refers to it (I am currently writing an article in which I discuss this issue in further detail). Among the various narratives on the phenomenon let us mention the case of Epimenides as reported to us by Diogenes Laertius (*Vitae philosophorum*, 1.109–110, ed. Long). Epimenides is searching for a lost sheep and finds a cave in which he falls asleep for 57 years. It is, in fact, the cave of a god of mysteries, who instructs him during his sleep about nature and the human body, and grants him the gift of divination. Having returned to the world of men, he is renowned for his wisdom and occult knowledge.

100 Moulé, "De la Pathologie aviaire au treizième siècle de notre ère."

101 Lazaris, "La production nouvelle en médecine vétérinaire," pp. 236–37. I will return to this new evidence in a study which is in preparation. Note that none of these manuscripts are illustrated. Despite the Byzantines' undeniable interest for this art, no miniaturist added a single picture. Of course, as B. Van den Abeele aptly wrote, 'hunting happens in the field, not in books' (Van den Abeele, *Texte et image dans les manuscrits de chasse médiévaux*, p. 7). Yet, other 'technical' Byzantine works were illustrated (see Lazaris, "Scientific, Medical and Technical Manuscripts").

little birds with birdlime and calling together with hunting the hare on foot, but now aristocratic hunting on horseback took precedence. With the exception of the ultimate confrontation between man and beast in the hunting of big game, hunting was mainly performed using raptors worn on a gloved fist. When aristocratic hunting became the norm, we then begin to find regular written and visual evidence of it.

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Veterinary literary production never ceased throughout the Byzantine civilisation. However, for quite some time, it has been felt that the advent of Christianity was the cause (or at least one of the major causes) of a slowdown in the development of the sciences and the loss of precious texts. For E. Leclainche fanatical monks scratched out or burned Greek and Roman parchments and because of this 'human barbarism,' humanity lost a valuable part of its scientific texts, in this particular case those dealing with veterinary medicine.[102] It is true that Christian scholars, by questioning the usefulness of pagan science and being fiercely opposed to its integration into the educational system of their time, contributed much to the modern idea that the decline of science had been brought about by Christianity. As was pointed out in the general introduction to this book, however, counter-movements existed from the very beginning of Christianity and throughout the history of Byzantine civilisation. It would be therefore extremely reductive to think that the advent of Christianity destroyed the development of sciences in general, or of veterinary medicine in particular. Many things did change, but we should stop talking about a decline.[103] On the contrary, the production of several original treatises by authors who lived at the very beginning and at the end of the Byzantine civilization demonstrates the Byzantines' keen interest for certain animals. The successive redrafting of some of these texts and their systematic reproduction (including the addition of original illustrations in some hippiatric manuscripts) reinforces this idea of a Byzantine civilization in which veterinary medicine was far more developed than previously thought. Among the animals that Byzantine veterinarians were most interested in, the horse, dogs and raptors were at the top of the list and the substantial number of passages relating to these animals confirms us in this view. Even if some texts concern other animals, it is likely that, in practice, when it came to cattle, goats, pigs or even sheep, veterinarians intervened less often than breeders themselves. Indeed, even if, from an early

102 Leclainche, *Histoire illustrée de la médecine vétérinaire*, t. 1, p. 82.
103 E.g. Boussarie, "La médecine vétérinaire populaire au Moyen Âge," p. 2.

date, professional veterinarians were required to treat animals, they never were the only ones or even the first ones to do it for all animals. Breeders and carers often preceded them when it came to livestock. As for men, for several centuries, there were two types of medicine, one for free men, the other for slaves. Similarly, for a long time there were two kinds of veterinary medicine: one for noble animals and another for all other commonplace animals.

CHAPTER 12

# The Byzantine Science of Warfare: from Treatises to Battlefield

*Thomas Salmon*

## 1 Introduction

> In every battle it is not numbers and untaught bravery so much as skill and training that generally produce the victory. For we see no other explanation of the conquest of the world by the Roman People than their drill-at-arms, camp-discipline and military expertise. (…) Scientific knowledge of warfare nurtures courage in battle.[1]

Vegetius (4th c./5th c. CE) expresses here the essential features of late Roman and later Byzantine concerns for performance in war. This chapter is an attempt to illustrate a new vision of Byzantine warfare in order to reveal its principles.[2] The Byzantine approach to warfare occupies a place within a long tradition and is one that still continues. More than the fundamental Greek and Roman knowledge they inherited, studying, theorizing and putting into practice this knowledge to improve ways to wage war has remained essential right up to our modern military academies.[3] Though technologies, and tools have evolved, methods and the general approach have not. Thanks to their excellent knowledge of what had been achieved by their predecessors and their rigorous analytic methods the Byzantines played a part in this tradition. This knowledge and analysis facilitated the learning, evolution, and transmission of

1 Vegetius, *Epitoma rei militaris*, transl. Milner, pp. 2–3. What has been translated into "Scientific knowledge of warfare" was originally "Scientia enim rei bellicae" in Vegetius' words.

2 We intentionally do not make use of the term "military science" in this chapter, as the term "science of warfare" seems more *à propos* and is less debatable.

3 The most striking example of the phenomena is the renewed interest for military classics within the U.S. Army in the 1980's and 1990's. This shows how far authors such as Sun Tzu, Maurice ou Clausewitz are still studied. See Wasinski, "La renaissance des études clausewitziennes," and on the *Strategikon*: Petersen, "The Strategikon," pp. 70–79.

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Byzantine science. We have to remember that the real object of our study is Byzantine science, but should this chapter, therefore, be fully committed to that notion? Not that the notion itself should remain unquestioned, but caution should prevail. Since many definitions of science exist it is useless to provide the reader with a single one. But it is both feasible and necessary to give an extended, or general contexts within which the term could meaningfully work.

The Aristotelian conception of science was dominant throughout the Byzantine period.[4] Subsequently science had much to do with the Greek notion of *episteme*, a theoretical ensemble which acted as a knowledge base which stressed out practical considerations. Indeed the term is often translated into the terms "science" or "knowledge" in Byzantine military treatises. Yet in those treatises *episteme* often goes beyond the reductive term "knowledge"[5] as it is also allied to practical implications, the proper experimentation and practice of knowledge. Indeed war was not an *episteme*, warfare was an *episteme*. And whereas war is a situation, warfare represents "the activity of fighting a war or strongly competing, especially with reference to the type of weapons used or to the way the fighting is done."[6] The Byzantine conception of the *taktike* itself refers to the definition of warfare or *polemon*, as being the ensemble of means necessary to win a war and to conduct an army.[7] Indeed war itself was not understood as a science by the Byzantines, but the ways to make it were. In the *Taktika* this ensemble is also referred to as a *techne*, to be understood as the

4 O'Meara, "Conceptions of Science in Byzantium," p. 170 summarized the Aristotelian conception of science and its profound bond with *episteme*: "The word "science" derives from the Latin *scientia*, which itself translates, in Cicero for example, the Greek word *episteme*. Aristotle stipulates what he means by *episteme* when he describes, in the famous introduction to his *Metaphysics* (1.1–2), how the human desire to know developed over time, from the experience of things given in sense-perception, through the accumulation of this experience to form certain practical skills, expertise, and arts, toward the emergence of a scientific form of knowledge, *episteme*. What separates science from lower forms of knowledge is that it concerns truths of general application rather than particulars, and that it is able to explain phenomena by referring to explanatory factors, to the causes of these phenomena." The Aristotelian conception of science was resumed, critisized and completed particularly by Alexander of Aphrodisias and the Platonist school of Alexandria, whose views on science largely influenced those of Byzantine scholars.

5 See "knowledge" in *Taktika*, Prologue, 6.

6 Cambridge dictionary, *Warfare*.

7 The anonymous treatise on strategy *De re strategica* notes: "Tactics is a science (*episteme*) which enables one to organize and maneuver a body of armed men in an orderly manner.," 14.3–4.

skill necessary to put this knowledge into practice in times of war.[8] Yet, comparing the combination of *episteme*/*techne* to a combination of theory/practice would be simplistic. The notion of *episteme* entails the application of knowledge rather than pure wisdom. This chapter was conceived as a constant exchange between *episteme* and *techne*, a unique combination reflected in the tactical conception and the use of weapons as it is prescribed in the military treatises and these treatises worked as a collection from which the Byzantines built their own typology of warfare. Combining, echoing Vegetius' words, inheritance with innovation, Hellenistic and Roman traditions together with contemporary innovation all acted as markers for the Byzantine science of warfare. This is about what Byzantines inherited from their predecessors and how they tried to profit from it. The role played by military treatises in the transmission of this knowledge was fundamental, and by blending theory and practice at all levels an impressive amount of technical and tactical information was derived from them. Although Byzantine military literature represents a significantly different corpus from what has been preserved from the ancient Greek period, it remains intimately connected to the Hellenistic/Graeco-Roman tradition of military writing. Byzantines freely reused material from ancient treatises, through a process that A. Dain called *retractatio*, although, as we shall see in this chapter, "slavish borrowings" seem to have been limited.[9]

Due to the strong historical and cultural influences, great caution must be applied to the content of Byzantine treatises since those influences can lead to an occultation of the true Byzantine elements of military writing. These elements really represent the science of warfare including most of the tactical and technical innovations.[10] Military treatises were indeed the incarnation of the Byzantine science of warfare, and the basis of military knowledge for both generals (*strategoi*) and high officers. They were one of the most essential tools of the Byzantine general as much during his military formation as when he was campaigning. One cannot help but be reminded of Constantine

8 *Taktika*, I.2, ed. Dennis; it has to be noted that warfare, when not directly refered to as *techne*, remains very much related to it. Warfare in Byzantium is conditioned on *techne*, therefore a constitutive part of warfare. The *Taktika* refered to here is a military treatise written in the late 9th-century imperial court, under the supervision of Leo VI (886-912). Most of these writings date from the 9th to the 11th century. More widely, the *taktika* designated treatises which had to do with positioning, placement, whether it was the ordering of troops on the battlefield or precedence at the imperial court. On the Greek *taktika* and their transmission, see Rance/Sekunda (eds.), *Greek Taktika*, especially the enlightening introduction by Rance, pp. 9–64 (with its own bibliography).

9 See Dain "Les stratégistes byzantins," pp. 318–19.

10 See Rance, "Maurice's Strategicon and 'the Ancients'" pp. 217–21.

VII's (913–959) advice to his son, the future Emperor Romanos II (959-963), to prepare a travelling library well stocked with "military manuals, books on mechanics, including siege machinery and the production of missiles and other information relevant to the enterprise, that is to say, to wars and sieges."[11] Their popularity can hardly be doubted as most of them cited precedents and inscribed themselves within current traditions, trying to improve and adapt what had been done previously. How they conveyed this knowledge is therefore an important matter, about which we unfortunately know very little. The little information we do have dates from the Komnenian era (1081–1185) and concerns the aristocratic and imperial milieux. It seems that military treatises were used as proper manuals within which experience from the elders occupied an important place. This can be detected in the advice authors gave to their readers.[12] The fact that the Byzantines were willing to transmit and make use of this knowledge can be observed in other remaining Byzantine manuscripts, which often combined Greek treatises with Byzantine ones and tactical treatises with poliorcetical ones,[13] Such information is scarce, however, and does not permit any generalization about how the science of warfare was transmitted in Byzantium.

This chapter aims at providing a comprehensive overview of some of the important features that characterized the Byzantine science of warfare. We have chosen, therefore, to focus on innovative material that impacted on the progress of warfare within the Byzantine empire. Treating every aspect would be the work of a lifetime, so only the main tendencies have been examined. This chapter, then, focuses on two main lines of enquiry, mostly as they were formed in the military treatises in Byzantium: siege warfare treatises and tactical treatises. Each part will provide the reader with an insight into treatises and their manuscript tradition, on prescriptions regarding the use of weapons and equipment, and on how they were actually used by the Byzantines. Since they could not be contained within a single chapter no special attention will be given to ruses and war tricks. The treatment here, however will hopefully give the reader an overview of both the theoretical and practical aspects of the Byzantine science of warfare. The most flourishing periods for this science were

11 Constantine Porphyrogenitus, *Three Treatises on Imperial Military Expeditions*, ed. Haldon, p. 107.

12 See Coufalová, "The noble illustrious warrior," pp. 7–8. No evidence of any kind of war academy has been yet found within Byzantine culture. Though teaching in institutions and academic structures may seem more of an anachronism.

13 Although being of a certain interest here, this chapter does not directly deal with manuscript tradition. Therefore we shall not extend our talk on this subject.

the early and middle Byzantine periods and since major innovations took place in these times they will be dealt with more fully here. An attempt will also be made to link the prescriptions of the manuals closely to what we know of their realization, and to link tactics as expressed in the treatises with some of the important contemporary technological innovations.

## 2 Siege Warfare: Heritage of the Antique

### 2.1 *Treatises on Siege Warfare*

Treatises provide many details of siege equipment and siege methods both in the words of their texts and through accompanying illustrations. Linking text and illustration is essential and studies have shown the importance of paying close attention to the presence of images in manuscripts, especially in scientific and military material.[14] Early on, Renaissance and early Modern antiquarians developed a taste for the study of historical war machines and technical treatises. Only two Byzantine treatises are exclusively concerned with siege warfare: the *Parangelmata Poliorcetica* of the so-called Heron of Byzantium[15] and the anonymous *De Obsidione Toleranda*,[16] both from the 10th century. We

14 Such studies also demonstrate the carefullness we have to employ towards these illustrations. On our subject see notably Parani, *Reconstructing the reality of images*, especially pp. 104–58; Bruhn Hoffmeyer, *Military Equipment*. On technical illustrations in Byzantine poliorcetical treatises, i.e. on the *Parangelmata poliorcetica*, see Sullivan, "Byzantine Offensive Siege Warfare," pp. 198–99 and Heron of Byzantium, *Parangelmata poliorcetica*, ed. Sullivan, pp. 8–14.

15 Heron of Byzantium, *Parangelmata Poliorcetica*, ed. Sullivan, pp. 26–113. Commentaries on the text can be found in idem., pp. 153–248. The treatise is edited, translated and commented on together with another one from the so-called Heron, the *Γεωδαισία* (Geodesia). It deals with the military application of the dioptra, a measuring instrument used initially as a surveying instrument for civilian constructions and astronomy in ancient Greek times. See Rossikopoulos, "The geodetic sciences in Byzantium," pp. 4–17. Both texts are preserved by the same manuscript, the Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 1605, whose tradition has been exhaustively studied by Alphonse Dain in Dain, *La tradition du texte d'Héron de Byzance*.

16 *De Obsidione Toleranda*, transl. Sullivan, pp. 139–263. This translation comes together with a reprint of the Greek text edited by Van den Berg, see *Anonoymus de obsidione toleranda*, ed. Van den Berg. Another treaty—identified and edited by Dain in "Mémorandum inédit," pp. 123–36—is translated by Sullivan as an appendix to his introduction. Originally in the Milan, Biblioteca Ambrosiana, B-119-Sup. Gr. 139, this text constitutes an alternative version of the *De Obsidione Toleranda*, and makes Dain and Sullivan conclude that they derive from the same original treatise on the defense of places. It would have

do not, in fact, really know about the authors of these two works. Dennis Sullivan points out some references to the topography of Constantinople in the *Parangelmata Poliorcetica*, concluding that its writer could have been familiar with the Polis, and may even have worked there.[17] Furthermore, In view of the nature of his writing, he must also have been familiar with both mathematical and mechanical material. The author of the *De Obsidione Toleranda* remains even more mysterious, since no distinctive element in the text leads us to any conclusion about him. Of the two, only the *Parangelmata Poliorcetica* deals directly with siege engines. Heron himself describes his work as a compilation and a clarification of ancient technical treatises seen as "wholly foreign now to most men and difficult to understand, because of the oblivion that comes with the passage of time, but also because the scientific terms are not familiar to the common speech."[18] Such authors as Biton and Philo Mechanicus (*c.* 3rd century BCE), Athenaeus Mechanicus (1st century BCE), Heron of Alexandria (1st century CE), Apollodorus of Damascus (1st–2nd century CE) were used by the tenth-century author to bring up-to-date poliorcetical knowledge to the middle Byzantine period.[19] Therefore, the treatise acts, from a mechanical point of view, as a bridge between the ancient and middle Byzantine knowledge of siege warfare. By contrast there is no particular focus on engines in the *De Obsidione Toleranda*, which is more like siege warfare as it is treated in tactical treatises. This text is created from a general/overall approach to siege warfare not simply focussing on technicalities but also allowing considerable importance to the psychological aspects of a siege.[20] What appears to be a dearth of

been written somewhere between the 7th and the 10th century CE. See Sullivan, "A Byzantine Instructional Manual," pp. 140–41 and Dain, "Mémorandum inédit," pp. 124–27.

17 Heron of Byzantium, *Parangelmata Poliorcetica*, ed. Sullivan, pp. 2–3. The author's name remains actually unknown, Heron of Byzantium being a convention deriving from a 14–15th century note by a commentator relating him to Heron of Alexandria. *Anonymus Byzantinus*, a more suitable designation, is not used in this chapter in order to distinguish him from other anonymous military writers. See also Martin, *Recherches sur la vie et les ouvrages d'Héron d'Alexandrie* and Dain, *La tradition du texte d'Héron de Byzance*.

18 Heron of Byzantium, *Parangelmata Poliorcetica*, ed. Sullivan, pp. 26–27.

19 For further information on ancient and Byzantine poliorcetic works and manuscripts, see Dain "Les stratégistes byzantins," and Hunger, "Kriegswissenschaft," pp. 321–40.

20 The author advises the general to encourage the besieged as more as possible, reminding him all the problems a besieger could face, the mortal nature of their ennemies: "[Be aware] that there is no need for the besieged [general] to capitulate, even if the siege threatens to be a lengthy one. For either the enemy forces will have disagreements with one another or some distractions may occur against the enemy's land from their hostile neighbours. ⟨One may hope that⟩ a scarcity of wheat and pestilential conditions may

actual technical treatises written by Byzantine authors is entirely explicable since from a technical point of view the authors probably considered these as sufficient. Construction methods for fortifications did not evolve in such a way as to force major innovations in the construction of siege engines, so maybe the Byzantines did not feel the necessity to provide technical treatises focussing only on siege engines.

The greater part of illustrative material can be found in the more ancient technical treatises. The illustrations in Byzantine copies of ancient technical treatises seem to belong to one of two traditions. Most illustrations followed the first tradition and were drawings that derived from Hellenistic/Graeco-Roman originals. Although they tend partly to sacrifice perspective in order to capture a bird's-eye view of the object described, some of these diagrams are so well drawn as to bear an uncanny resemblance to modern schematics. On the other hand, the main feature of the second tradition of manuscript illumination involves the inclusion of artistic representations of the finished war engines in action. These seem to emphasize the practical aspect of such manuscripts, and how they might be used. The innovative character of Byzantine scientific illustration took this approach, just as treatises did. The great precision of the diagrams found in engineering manuscripts from the Byzantine period should not lead to the assumption that their interpretation is easy. To see this issue more clearly, it is essential not to view these illustrations as works of art. Rather they were intended to act as visual supports for the textual data which described engines and their use.

### 2.2 *Siege Artillery*

Byzantine siege artillery was largely inherited from the Greek/Hellenistic and Roman periods. The fact that some Byzantine authors expressed no need for new poliorcetics in their treatises is not entirely the result of some kind of "conservatism" on their part nor does it signify a blind reliance upon ancient methods. On the contrary, the Byzantines were perfectly able to discriminate what to keep and what was obsolete in the ancient science of siege warfare. The *Taktika* itself notes:

> In a word, there are other machines and engines that, upon investigation, you will find in other historical works and more fully in the expositions of the strategists. (…) How are they constructed? How are they moved

occur when large forces remain in one place for a long time, or even that the leader of the army may always suffer some mishap, as he is human and subject to incapacitation due to multiple accidental causes," Sullivan, "A Byzantine Instructional Manual," pp. 150–51.

> forward? In what kind of places under siege? Not only will you be able to bring about the construction and erection on site of these machines but you will be helped by the practical knowledge of the artillerymen with you and of the men familiar with such equipment.[21]

The *Parangelmata Poliorcetica* also reflects this; the two treatises directly refer back to ancient poliorcetical manuals, and the *Taktika* prescribes the use of engines only when the siege demands it.[22] These machines are of all kinds: stone (and sometimes dart)-throwing artillery, siege towers, rams, or ladders. All these engines are quite accurately depicted in a series of manuscripts that contain both poliorcetical and tactical manuals.[23] Bolt-throwing artillery, in the popular imagination at least, is probably the most emblematic type of siege engine which characterized late antique and medieval warfare. In this the Byzantines inherited the main features of their knowledge of siege artillery from their Greek/Hellenistic and Roman predecessors. The engines took various forms: from the small hand-held ballista to the great traction trebuchets. As we shall see below, Byzantine sources often speak about these engines, whether in poliorcetical and tactical treatises or even in historical works. There were many words used to designate them in Byzantine literature; although siege artillery faced the same problem as other technical military terms because the extensive use of generic terms, all too often, makes distinctions between them impossible. Throughout the Byzantine period, dart, bolt and stone-throwing engines were designated mostly by the terms μαγγανικὰ (*manganika*), πετροβόλα (*petrobola*), λιθοβόλα (*lithobola*), τοξοβόλα (*toxobola*),

21 *Taktika*, XV.29, ed. Dennis.

22 See Heron of Byzantium, *Parangelmata poliorcetica*, ed. Sullivan, pp. 27–29. See also *Taktika*, XV.7, ed. Dennis.

23 Several families of manuscripts emerge from such compilation as this, the most remarkable being that of Paris, Bibliothèque Nationale de France, gr. 2442, Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 1164 and Madrid, Real Biblioteca del Monasterio de San Lorenzo de El Escorial, Y.III.11 (gr. 281). Vat. gr. 1164 was copied in the late tenth or more probably the first decades of the eleventh century and its production can be traced to the scriptorium of Ephraim in Constantinople. It was in the same scriptorium and at roughly the same time that its sibling, Par. gr. 2442, which was copied from the same exemplar; the manuscript originally formed part of a single volume along with Vatican, Biblioteca Apostolica Vaticana, Barb. gr. 276). Escorial. gr. 281, mostly containing works of ancient and Byzantine tacticians, was copied from Vat. gr. 1164 in the 1020s or 1030s. It used to form part of a large parchment book with Napoli, Biblioteca Nazionale, III.C.26; the break between the two manuscripts is located in the part containing Philon's manual on artillery construction.



FIGURE 12.1 Byzantine soldiers using a rope-pulled trebuchet

βαλλίστρα (*balistra*), πολιορκητικά (*poliorketika*), ὄργανα (*organa*), μηχαναί (*mechanai*) and their compounds.[24] Several modern studies have tried to identify some of these engines by means of the specific terms employed. G.T. Dennis identified the ἑλοπόλις (*helopolis*) as being a trebuchet, more specifically a traction trebuchet operated by several artillerymen pulling down ropes as a counterweight to throw the bolt (Fig. 12.1).[25]

24 For discussion about these terms, see Dennis, "Byzantine Heavy Artillery," pp. 99–115. On terminology, see also Makrypoulias, "Ἡ μελέτη της Βυζαντινής πολεμικής τεχνολογίας," pp. 31-44.

25 Two other sharp depictions of rope-pulled trebuchets can be found in the Madrid, Biblioteca Nacional de España, Vitr. 26.2, fols. 151, 166, 169, also Grabar/Manoussacas, *L'illustration du manuscrit de Skylitzes*, figs. 193, 213. Dennis, "Byzantine Heavy Artillery," pp. 100–101 stated that the Greek term ἀλακάτια also designated a traction trebuchet, whereas Haldon thinks more of an engine similar to the Roman *carroballista*, as it would be "a carriage-based, swivel-mounted tension or torsion-powered weapon," cf. Haldon, *Warfare, state and society*, p. 136. Heron of Byzantium, cited by Sullivan, comments on the engine: "the construction of the one-arm (μονάγκωνος) ⟨device⟩ will furnish those who wish it with theory about catapults (καταπαλτικὴν θεωρίαν), as it brings together much for long-range shooting with euthytone and palintone engines, i.e. stone shooters (λιθοβόλοις) and missile shooters (ὀξυβελέσιν)," Sullivan, "Offensive Siege Warfare," p. 198; Heron also tells us about the machine as being "in the form of a palintone arm (ἐν σχήματι παλιντόνου ἀγκῶνος)," Heron of Byzantium, *Parangelmata poliorcetica*, ed. Sullivan, pp. 90–91. This strongly suggests that the ἀλακάτια resembled more an onager than a *carroballista* or a traction trebuchet. This view is supported by Leo VI's *Taktika* advice: "If there are houses within the fortified city that can be easily set on fire, shoot a constant barrage of fire-bearing arrows in many directions, especially if there is a strong wind blowing, and set them on fire, affixing inflammable material to the arrows (τῇ σαγγίτῃ), by means of the

The *Miracula S. Demetrii* gives a detailed description of such engines used by the Avars and the Slavs during the siege of Thessalonica in 597:

> These were tetragonal and rested on broader bases, tapering to narrower extremities. Attached to them were thick cylinders well clad in iron at the ends, and there were nailed to them timbers like beams from a large house. These timbers had the slings from the rear and from the front strong ropes, by which, pulling down and releasing the sling, they propel the stones up high with a loud noise. And on being fired they sent up many stones so that neither earthen nor human constructions could bear the impact.[26]

Contrary to many other siege engines, the rope-pulled trebuchet was probably not in use in the Mediterranean basin in Roman times. Whether the Byzantines invented this kind of artillery or whether they got it from another culture remains unclear. Even though Theophylaktos Simokatta claims that the Byzantines taught the Avars about this weapon, it could equally well be the other way around. Since the Chinese employed it some centuries before, it could have passed to nomads such as the early Avars and other Steppe people coming from Central Asia and then reaching Byzantium through contact with them.[27] Besides, Pseudo-Maurice's *Strategikon* tells about some new features regarding soldiers' equipment that had been borrowed from the Avars.[28] If not a Byzantine development, the trebuchet could have reached Byzantium the same way, at least in the 6th century. Similarly, Muslim military engineers most probably learnt it from the Turks that came down from the Caucasus in the 7th century.[29] However, this new kind of artillery adopted by the Byzantines proved that they relied not only on ancient engines. Further-

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stone-throwing machines that are called *alakatia* or *tetrareai*, and hurl stones filled with inflammable material against the houses and they will burn easily." *Taktika*, XV.26, ed. Dennis; *σαγγίτῃ* could well mean "projectiles" in general, not only arrows, and for a siege engine to be able to shoot on houses inside a fortified city, a ballista-type weapon would be ruled out. Also, the device is transported on carts, not carried, cf. *Taktika*, V.6; VI.23; XIV.74, ed. Dennis.

26 Vryonis, "The Evolution of Slavic Society," p. 384, also in Dennis, "Byzantine Heavy Artillery," p. 102.

27 For a complete overview on the appearance of the trebuchet in China, see Needham/Yates/Gawlikowski, *Science and Civilisation in China*, vol. 5.6, pp. 203–31, especially pp. 206–08.

28 See *Strategikon*, I.2, ed. Dennis/Gamillscheg.

29 See Needham/Yates/Gawlikowski, *Science and Civilisation in China*, vol. 5.6, pp. 231–40; Hill, "Trebuchets," pp. 99–103.

more, the first known appearance of a Byzantine counterweight trebuchet occurs in the account of the siege of Zevgimon in 1165,[30] and together with the rope-pulled trebuchet, it continued to be used by the Byzantines until the mid-15th century. This kind of siege engine seems to have been very popular in the Byzantine period—especially the rope-pulled trebuchet. Maybe even more so than the torsion and tension machines such as ballistae. These are unknown in Byzantine art, except for the ancient χειροβαλλίστρα.[31] But ballistae are more easily identified, since the term βαλλίστρα or its derivatives were employed by the Byzantines to characterize these weapons when generic terms were not. Two main types of ballistae were developed from antiquity onwards. These were identified by their power systems: torsion and tension. This distinction has been applied to dart-, bolt- and stone-throwing engines in the Mediterranean world since their invention by the Greeks, probably around the 4th century BCE. Originally, they were mainly made of wood, hemp and animal sinew. As P.E. Chevedden pointed out, ballistae were greatly improved in Roman times, for they were reinforced and protected with metal, and some parts of the engines were even made entirely of metal (iron, bronze or steel); even the sinew-ropes were protected by metal cylinders.[32] It appears that use of torsion and ballistae went into a decline from the early Byzantine period onwards and were never used by the Byzantines on a large scale. They were very expensive, both to make and to maintain, and needed the attention of specialized engineers. Although more powerful than a tension-powered engine the torsion

30 The stone-propulsion system of a counterweight trebuchet consists of a chamber filled with weights (often stones) at the end of the great arm of the machine. The sling at the other end of the arm was attached to the carriage and then, under the effect of the weights, was released. In this way the stone was thrown. For the account of the siege of Zevgimon, see Niketas Choniates, *Historia*, ed. Van Dieten, pp. 134–35. This is the first certain mention of the engine, as its description leaves no doubt as to its counterweight system: "Next, filling the fosse with mud and rubbish, as there was a lack of stones, and positioning the stonethrowing engines round about, he gave the command to bring down the walls. When all were put into operation, discharged stones of a talent weight weakened the walls' joints. Andronikos took charge of a stonethrowing engine and by using the sling, winch, and screwpress, shook the section of the wall between the two towers violently. Struck by the weighty stones and sapped by miners as well, the wall began to crumble and fall over.," Niketas Choniates, *Historia*, ed. Van Dieten, pp. 134–35.

31 For the illustrations in Byzantine manuscripts, see Paris, Bibliothèque Nationale de France, Suppl. gr. 607, fols. 56r–58v; Par. gr. 2442, fols. 68v–70v; Vat. gr. 1164, fols. 107v–109v. For an exhaustive list of depictions, see Prou, *"La Chirobaliste,"* pp. 1–319, p. 115, resumed in Lazaris, "Scientific, Medical and Technical Manuscripts," p. 110, n. 249.

32 See Chevedden, "Artillery in Late Antiquity," pp. 135–37 and p. 154.

engine was rather more fragile.[33] However, there is evidence for the use of the torsion-powered ballista throughout the middle and late Byzantine periods. W.S. Tarver and P.E. Chevedden pointed to the fact that the torsion ballista fell into disuse after 4th/5th centuries CE. They argue in favour of a singular meaning for the term τοξοβολίστρα: the engine frame would be shaped like a bow (τόξον) made of a single section.[34] This interpretation, is both logical and tempting but does not prove that there was a decline in the use of the torsion ballista, or more broadly a decline of the torsion-powered system. The various Latin terms that are used to describe ballistae do not enable us to clarify the Greek terms. The *carroballista*, meaning "mounted on a cart," does not have an equivalent in Byzantine times. It has been argued whether or not the *cheirobolistra* (χειροβολίστρα) and the *toxobolistra* (τοξοβολίστρα) were the Byzantine equivalents for the Roman *manuballista* and *arcuballista* respectively. During the Byzantine period, the *cheirobalistra* only occurs in Constantine VII Porphyrogennetos' impressive *De Administrando Imperio* to characterize a weapon used by the Chersonites in the 4th century CE:

> They gathered together the men of the neighbouring forts and constructed military waggons and placed in them the so-called arbalests (χειροβολίστρας).[35]

And a few lines later in the text:

> They made a show of flight, not having exposed the arbalests (χειροβολίστρας) they had made, that were in their waggons.[36]

These passages leave little doubt as to the nature of the *cheirobalistra*. It should therefore be seen as a small bolt/dart projecting engine, of the same kind as the *carroballista* or the *manuballista* described by Vegetius.[37] In the light of the

33 Chevedden, "Artillery in Late Antiquity," p. 164.

34 Contrary to a torsion ballista, made of a two-armed frame, with each arm being maintained by a vertical spring of sinew or hair-made ropes. For the view of the decline of the two-armed torsion engine, see Tarver, "The Traction Trebuchet," p. 142 and n. 36; Chevedden, "Artillery in Late Antiquity," p. 148 and pp. 163–64. Haldon, *Warfare, state and society*, pp. 134–35 agrees with this point of view.

35 Constantine Porphyrogennetos, *De Administrando Imperio*, ed. Moravcsik, English transl. Jenkins, p. 259.

36 Constantine Porphyrogennetos, *De Administrando Imperio*, ed. Moravcsik, English transl. Jenkins, pp. 259–61.

37 That *cheirobalistra* would be an incorrect translation of *carroballista* as Huuri thinks would be quite unlikely, cf. Huuri, "Zur Geschichte," p. 75, n. 3. It is unlikely that the

lists of equipment needed for several expeditions to Crete in the mid-10th century, *toxobalistra* seems to be another bolt/dart projecting engine, with a smaller declination: the *cheirotoxobolistra* (χειροτοξοβολίστρα). It would then be similar to the *arcuballista* and the *manuballista*, perhaps bigger than the *toxobolistra*, at least for the kind of projectile they used to throw. It should be noted that siege artillery such as small trebuchets or ballistae could be used by the besiegers as well as the besieged, either to try to shake or break down walls or to disrupt the besieging enemy.[38] The larger siege engines were used almost only for besieging or for sea warfare, not as field artillery. Because of their size and weight they had to be constructed *in situ*. Their employment (and their existence) depended therefore on resources brought for the siege or found around the besieged area. The smaller engines were transported in separate parts in carts.[39] However, without wishing to exaggerate a supposed decline in the use of siege artillery by the Byzantines, some sources clearly indicate it was not their favourite technique for use during a siege. Byzantines undoubtedly preferred to take a city without casualties, using instead men working from within, various forms of treachery or when possible, negotiation.

### 2.3 *Other Siege Engines and Methods*

Artillery was not the only kind of engine used in taking a stronghold, or even in defending it. In both cases soldiers, to get to the stronghold's walls, had to be protected from enemy projectiles, whether those projectiles were artillery or other types. It is quite remarkable that almost all of them are discussed and appear in illustrations in Byzantine copies from ancient treatises, sometimes mechanical, sometimes tactical. Not every engine will be afforded a full description here, and only those for which we have evidence of use will be discussed. Though, Heron of Byzantium remains the most exhaustive treaty for this kind of equipment, and even gives a complete list at the beginning of the *Parangelmata poliorcetica*:

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emperor Constantine VII made such mistake in the translation. Besides, translating Latin military terms into Greek was a current practice in the middle Byzantine Period. The distinction between *carroballista* and *manuballista*—besides their size—remains unclear and the rapprochement with the *carroballista* cannot be ruled out. See Vegetius' description of the *carroballista* in Vegetius, *Epitoma rei militaris*, 2.25, 3.24, ed. Reeve; see also a résumé of the debate around late Roman/early Byzantine ballistae in Chevedden, "Artillery in Late Antiquity," pp. 138–42.

38 At the siege of Zevgimon by Manuel I Komnenos mentioned on p. 439 above, Hungarians used such engines from the walls, see Niketas Choniates, *Historia*, ed. Van Dieten, p. 134. See also *De Obsidione Toleranda*, ed. Sullivan, p. 161.

39 See *Taktika*, V.6, ed. Dennis.

> There is a need of machines for conducting a siege: different types and forms of tortoises, such as excavating tortoises, filler tortoises, ram-carrying tortoises, tortoises with wheels in front, and plaited *laisai*, recently invented and very light, wedge-shaped beak ⟨tortoises⟩ to protect against heavy rolling objects, wicker tortoises; and wooden caltrops 5 *pecheis* (about 2.3 m) in height; rams both composite and of a single piece of wood; portable wooden towers, which are easy to procure; different forms of ladders, composite and very light; also protection against heavy objects that are raised high ⟨to drop⟩ and against ⟨flames⟩ ignited by incendiaries; scout-ladders for viewing things inside ⟨cities⟩; different tools for digging through different kinds of walls; drop-bridges useful for all types of ditches; machines for mounting walls without ladders; siege machines that do not fall over for use against coastal cities; bridges for en masse river crossings of large numbers of men in good order.[40]

Leo VI's *Taktika* adds recommendations for the best ways of employing some of them:

> With the assault then being carried on in a circle all at once, the besieged will fall into helplessness and dejection, especially when, along with the ladders, you move the other machines into place, such as rams, tortoises, towers, or other siege engines. If you bring up the siege engines and, at the same time, set the ladders against the wall, the people within will be harassed from many directions. If they neglect the other sections of the wall in order to concentrate their defense against the engines that have been moved up, the men bringing up ladders will encounter no strong opposition and will easily climb up onto the wall. Even if they divide their own forces to confront the men bringing up ladders, then those who are bringing up the machines will make their attacks all the more forcefully.[41]

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40 Heron of Byzantium, *Parangelmata poliorcetica*, ed. Sullivan, pp. 199–200.

41 *Taktika*, XV, 19, ed. Dennis. This is already known to Onasander (*Strategikos*, 42.4–6, ed. & transl. Oldfather). See also Sullivan, "Offensive Siege Warfare," p. 188. The *Taktika* gives a less detailed list of siege engines: "There are the ones called rams (κριοί) that pound the walls and shatter them. There are also the towers (πύργοι) constructed of wood covered with hides or other materials so they will not be destroyed by fire. Wheels are used to bring them close to the walls and from the top soldiers fight against the people on the walls. Tortoises (χελῶναι) are also brought up to the walls to undermine their foundation. Composite ladders (σκάλαι σύνθεται) are set up against the walls or placed on rigid wooden beams and brought forward on wheels.," *Taktika*, XV.27, ed. Dennis. However, this list probably reflects those engines commonly constructed and used.

Similar recommendations are to be found in most of the tactical treatises in the middle Byzantine period.

### 2.4 *Muscular Power to Breach the Walls*

Rams were common siege engines. They needed less material in their construction—essentially wood—and were covered with hides to protect them from fire damage. In contrast, less labour was needed to move rams forward than towers, and so fewer besiegers were protected by the engine. Another way for besiegers to breach the walls was to dig tunnels under them. While digging, soldiers were protected by tortoises (χελῶναι). These were devices designed as wheeled wooden roofs, usually covered with hides. Notably, different types of tortoise are depicted in the Vat. gr. 1605, Vat. gr. 1164 and Par. gr. 2442.[42] It seems that sapping was quite popular among Byzantine generals and several uses of tunnels are recorded.[43] The Byzantine period saw no major innovation with regard to this siege equipment or siege methods, except for the *laisai*. Heron of Byzantium mentions "plaited *laisai*, recently invented and very light."[44] We can tell from both the description and the illustration in the Vat. gr. 1605, that *laisai* resemble wooden parapets protecting soldiers. They are covered "with clay or with ash mixed with blood and covered with the hides of freshly slaughtered cattle against incendiaries and boiling liquids poured over them."[45] Nikephoros Ouranos' detailed description stands as an example of the very practical side of Byzantine treatises written by generals:

> You must issue instructions to the entire army to prepare the implements used in siege warfare, *laisai* made either from vine stalks or from branches of willow or mulberry trees. These must be woven together and in great numbers. They [the *laisai*] should be like a house in shape; the upper section, that is, the roof, must be quite sharply peaked. They should have two doorways, and each *laisa* must have room enough for fifteen to twenty men. Hanging over the opening in front it should have a piece

42 Vat. gr. 1605, fols. 7v, 8r, 35r, 35v; Vat. gr. 1164, fols. 119r, 123v, 124r; Par. gr. 2442, fols. 80r, 84v, 85r.

43 *Taktika*, XV, 27–28, ed. Dennis; Heron of Byzantium, *Parangelmata poliorcetica*, ed. Dennis, pp. 43–45; Nikephoros Ouranos, *Taktika*, ed. McGeer, 65.19–21. For examples of tunnels used in sieges in historical accounts, see Leo the Deacon, *Historia*, ed. Hase, pp. 25–26, a passage most probably modeled on Agathias, *Historiae*, ed. Keydell, pp. 21–22.

44 Heron of Byzantium, *Parangelmata poliorcetica*, ed. Sullivan, p. 29.

45 *Heron of Byzantium, Parangelmata poliorcetica*, ed. Sullivan, p. 259. For an illustration containing *laisai*, see Vat. gr. 1605, fol. 8r.

> made from the same branches acting as a screen to receive projectiles shot from the wall and protect the men inside. […] The *laisai* must not be heavy, impossible to lift, but should be rather light, so much so that it is possible to lift and carry them up to the walls, then easily withdraw them once again.… Have the men fix the *laisai* near the wall at a distance of five to ten *orguiai* [roughly 10–20 m], and they should bombard the enemy, some with arrows, some with slings; others using the catapults must bombard both the walls and the enemy with stones, while men with sledgehammers and battering rams must break apart the walls.[46]

*Laisai* were used by besiegers as well as by the besieged and were quite popular. It seems the term may have covered all the different light parapets, including wheeled ones. Unfortunately for besiegers, rams or tunnels couldn't always reach through the walls of a stronghold, so that towers and/or ladders had to be constructed.

### 2.4.1 Get to the Top of the Walls

Byzantines not only used simple composite ladders to climb the walls of a structure, they also operated larger ones mounted on wheeled frames. These wheeled ladders, which did not seem to have been known to ancient authors, are mentioned by Heron of Byzantium in the *Parangelmata poliorcetica*, and pictured in the Vat. gr. 1605.[47] Apart from being wheeled—and so usually less tiring to advance to the walls—these ladders allowed more soldiers to climb simultaneously. This was also an advantage of siege towers, that could both bring soldiers to the walls and protect them. As mentioned above, small siege artillery could be mounted on and fire on the defenders.[48] Huge towers that integrate one or two rams on the medium or high level are pictured in the Vat. gr. 1605.[49] Some towers could even be mounted on yoked boats to get to walls by sea. According to John Kaminiates, Leo of Tripoli's fleet made use of similar engines during the siege of Thessalonica in 904:

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46 This translation is to be credited to E. McGeer. See McGeer, "Tradition and Reality," p. 135. For further information on the *laisai*, see McGeer, "Tradition and Reality," pp. 135–38 and Sullivan, "Byzantine Offensive Siege Warfare," pp. 196–97.

47 See Heron of Byzantium, *Parangelmata poliorcetica*, 46, ed. Sullivan and Vat. gr. 1605, fols. 11r, 12v.

48 See p. 441.

49 Vat. gr. 1605, fols. 20r, 29v and 30v. These composite machines were already known to classical poliorcetics authors such as Athenaeus Mechanicus and Apollodorus of Damascus, see Apollodorus Mechanicus, *Poliorcetica*, ed. & transl. Lacoste, pp. 258–68.

> Lighting lamps everywhere, they coupled the ships together in adjacent pairs and lashed their sides together with stout cables and iron chains so that they would not easily drift apart. Then they hoisted by means of the rigging at the fore the pieces of wood that stand up in the middle, which sailors call masts, and attaching by their handles to these the steering-paddles of each ship, they slung them high up in the air across the ropes leading to the prow so that their blades projected beyond the side of the ship. The result was a remarkable and novel contraption. For when the steering paddles had been suspended aloft by their handles in the manner described, they placed long strips of wood over them in rows, one next to the other, flooring in by this ingenious method the intervening space. They then fenced in the edges on all sides with boards, and secured the ends of the steering-paddle handles by making them fast to very strong cables at the stern end of the ships. In this manner they devised towers that were more effective than those surmounting walls on dry land. In them they posted armed barbarians, an elite force mounted aloft on account of their physical strength and natural daring and destined to deal us the coup de grace.[50]

These ladder-type engines constituted one of the major Byzantine innovations in siege engines, another indication of the evolution of siege warfare and science within the Byzantine world.

#### 2.4.2 Greek Fire

The most impressive device developed by the Byzantines was the so-called "Greek fire." Although most prominently used on ships, it is mentioned in other contexts as "siege warfare."[51] What we now call Greek fire seems to refer to not one but several mixtures productive of liquid fire (*hygros pyr*) when ignited. Most likely it resembled some sort of oil or petroleum that could not be extinguished by water. It was propelled by *siphones* set on the *dromones*' bows and used directly to set fire to enemy ships. *Siphones* were most likely composed of a pump and a bronze tube in which the liquid was ignited.[52] The

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50 John Kaminiates, *De expugnatione Thessalonicae*, 32, ed., transl. Frendo/Fotiou/Böhlig.

51 Heron of Byzantium, *Parangelmata Poliorcetica*, ed. Sullivan, pp. 84–85; *Sylloge Tacticorum*, LXIII.8, ed. Dain.

52 There is still discussion as to how the liquid might have been propelled and whether the *siphon* designated the whole device or just the pumping system. For an exhaustive resume on the debate, see Pryor/Jeffreys, *The age of the ΔΡΟΜΩΝ*, pp. 607–31 and Haldon, "'Greek Fire' revisited," pp. 290–325.

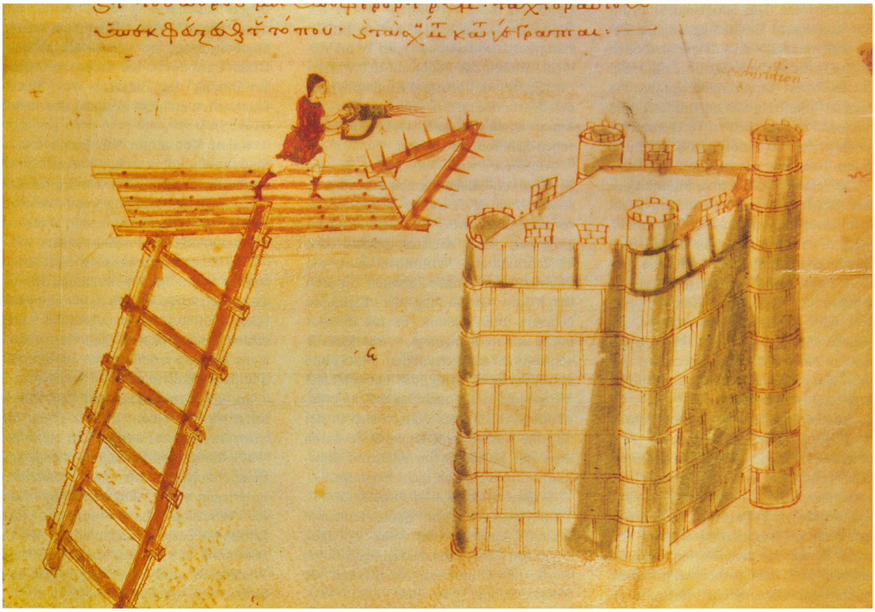


FIGURE 12.2 Soldier throwing Greek fire with a hand-*siphon*

chronicler Theophanes first noted its use by the Byzantines during the Arab siege of Constantinople in 673/4–678:

> At that time Kallinikos, an artificer from Heliopolis of Syria, having taken refuge with the Romans [and] having prepared sea fire, ignited the ships of the Arabs and burned them with their crews. In this way the Romans came back in victory and acquired the sea fire.[53]

A Byzantine soldier holds a portable version of this device in the Vatican manuscript of the *Parangelmata Poliorcetica* (Fig. 12.2).[54] Greek fire could also be contained in terracotta grenades thrown at the enemy from either siege engines or by the soldiers themselves. Evidence for its use, however, remains scarce, and consists mainly of just a few texts.[55]

53 Theophanes the Confessor, *Chronographia*, transl. Mango/Scott, p. 494.

54 See Vat. gr. 1605, fol. 36r; this device is said to have recently been invented by the emperor in *Taktika*, XIX.64, ed. Dennis and in *Sylloge Tacticorum*, LXIII.8, ed. Dain.

55 The Madrid Skylitzes preserves an illustration of its use in naval context, see Vitr. 26.2, fol. 34v.

## 3 Personal Weaponry and Equipment: Where Tactics Meet Technique

One of the most prominent fields of the Byzantine science of warfare was weaponry. The strong Byzantine cultural heritage as well as encounters with various people such as Steppe nomads forced the Byzantines to constantly adapt their weaponry. The science of warfare cannot do without technical material. But this material far from being antagonistic to the Byzantine notion of *episteme*, is actually complementary to it. The various types of weapons developed by the Byzantines, weapons that were the product of their military knowledge and which they accumulated over a period of time, will be explored in what follows.

### 3.1 *Tactical Treatises*

As opposed to technical treatises, Byzantine tactical treatises seem to be the most valuable sources in identifying the special Byzantine features of their military literature. Except for Vegetius' *Epitoma rei militaris* (4th–5th century CE) and Pseudo-Maurikios *Strategikon* (6th century CE), almost all the tactical treatises that have come to us date from the middle Byzantine period, especially the 10th and 11th centuries. From the beginning of the 7th to the middle of the 9th century only the so-called *Strategikon* of Syrianos Magistros and several anonymous fragmentary texts have been recovered.[56] The lack of late Byzantine military writing contrasts with previous centuries. Only one treatise by Theodore Palaiologos, marquess of Montferrat (1306–1338) survives. It is called *Instructions and Prescriptions for a Lord Who Has Wars to Wage and Governing to Do*,[57] but it is a text which can hardly be considered Byzantine as the author spent much of his life in 14th century Italy and is clearly more applicable to western governance and western military thinking. Some sources indicate the existence of other military writings from the period but these are now

56 Syrianos' work won't be dealt with in this chapter. The work is now thought to be 9th century, but as it contains no conclusive evidence for its dating, its recommendations are of little help. Indeed they provide no assistance on any datable material or development in the Byzantine science of warfare. For further information on Syrianos and his work, see Rance, "The date of the military compendium of Syrianus Magister," pp. 701–37 and the exhaustive bibliography used by the author. Fragments of another treatise from a so-called Urbikios has come down to us but provides nothing of use. On Urbikios' treatise, see Dain, "Les stratégistes byzantins," pp. 340–42.

57 The text was originally written in Greek during the author's stay in Constantinople and translated into Latin by him some time after. Only the prologue of the Latin edition, and two later French translations (14th and 15th centuries) survived. For a modern French edition/translation see Theodore Palaiologos, *Instructions and Prescriptions*, ed. Knowles.

lost.[58] Although most of these treatises and the context of their composition have been exhaustively studied, the reasons for such temporal gaps between them remains unknown. Logically, one might expect a significant amount of lost material and writing. But some compilations like the *Suda*, an important tenth-century "encyclopaedia," does not mention any lost military works of which we are not already aware or that would fill the gap.[59] The passion to record appears to be one of the most important reasons, if not the most important, for committing these tactical treatises to writing. In the *Strategikon*, as well as in the *Taktika* of Leo VI (end of the 9th century), the authors explicitly express a desire to commit to writing events often related to the military situation at the time.[60] At a later date, fashion might have acted as a stimulant to authorship but it was neither the starting point nor the trigger for the phenomenon. The resemblances between these two treatises go beyond the simple issue of literary tradition. Even if the *Taktika*, as well as the treatises that follow, are inscribed in the Macedonian cultural context,"[61] each one is very unusual and has its own peculiar features. As we will see in the details that follow, the content reveals a substantial degree of innovation both in the vocabulary employed or, more importantly, technically and tactically. The fact that some are tactical does not mean they do not contain technical details of equipment or weapons. For example the *Taktika* lists the complete equipment of a cavalryman, just as the *Strategikon* did four centuries previously, and the *Sylloge Tacticorum* half a century later, and this is even more precise.[62] Instead

58 Theodore Palaiologos, son of emperor Andronikos II (1282–1328), inherited the March of Montferrat from his mother Irene of Montferrat and left Constantinople for northwestern Italy in 1306 at the age of 15 or 16 to become marquess. He then went to Constantinople several times, and wrote the treatise there. Though, except for a few passages, "Theodore was thoroughly Westernized and his treatise generally reflects Western practices" as Bartusis, *The Late Byzantine Army*, p. 323, concludes. These few elements, although interesting, do not quite fall within our scope here. Michael Tarchaneiotes is said to have written a military treatise but no manuscript has yet been discovered, according to Bartusis, *The Late Byzantine Army*, p. 10.

59 See *Suidae Lexicon*, ed. Adler. For a current English translation of the Suda, see <http://www.stoa.org/sol/history.shtml>.

60 Maurice, *Strategikon*, transl. Dennis, pp. 68–73; Leo VI, *Taktika*, I, 5–6, ed. Dennis.

61 The "Macedonian renaissance" refers to a cultural advance associated with the reign of the Macedonian dynasty (867–1056). On this phenomenon, see Flusin/Cheynet (eds.), *Autour du* Premier humanisme byzantin.

62 *Taktika*, V.1–4; VI.1–14, ed. Dennis; *Strategikon*, I.2; *Sylloge Taktikon*, XXX.2, XXXVIII.5, 7, 10, XXXIX.2, 9, ed. Dain. Many parts of the *Sylloge Tacticorum*, including the armament of a cavalryman, are repeated in the *Taktika* by Nikephoros Ouranos; see Nikephoros Ouranos, *Taktika*, 60, ed. McGeer.

of presenting their advice to the reader in a straightforward and direct way, the texts are addressed to a general or to any high officer of the Byzantine army. Although the second person pronoun "you" is almost never seen in military treatises, the writing style offers few embellishments. The information is given in clear and simple statements. The authors themselves usually had close links with the military and aristocratic milieu of the empire. It is likely that Emperor Nikephoros II Phokas (963–969) wrote the *Praecepta Militaria* (10th century CE) and gave his orders and his notes for the composition of the *De Velitatione* (10th century CE). The *Strategikon* and the *Taktika* were composed by someone in the inner circle of the emperor, and written on his orders and under his guidance.[63] The anonymous *Sylloge Tacticorum* (10th century CE), *De Re Militari* (10th century CE), Nikephoros Ouranos' *Taktika* (10th–11th century CE), and Kekaumenos' *Strategikon* (11th century CE) were composed either by generals or by experienced officers.[64] It should be pointed out that these writers are too often seen only as military men who happen to write rather than authentic authors or scholars. Yet it is clear from their work that they should be considered as such. Their undeniably high literacy, their military knowledge and their undoubted experience combined to permit these generals to compose highly polished scientific, military treatises. Whether they were generals or emperors, they might possibly have been Byzantine scholars. Vegetius himself was not an army officer, but since his name is associated with the titles of *vir illustris* he certainly held a high office in the imperial administration. His knowledge of the way in which the army functioned together with related legal and financial details all strongly suggest that he was intimately aware of the conditions within the army of the time.[65] Although not a soldier himself,

63 On the authorship of the *Strategikon*, see Maurice, *Strategikon*, ed. & transl. Dennis/Gamillscheg, pp. 15–18; for an exhaustive discussion on authorship of the *Taktika* see Haldon, *A Critical Commentary*, pp. 25–33. J. Haldon considers Leo VI to be the author of the *Taktika* as long as he largely influenced the writing of the text, although it is almost certainly not from his own hand.

64 On the anonymous authors of the *Sylloge Tacticorum* and the *De Re Militari*, see Dain, "Les stratégistes byzantins," pp. 357–58, 369.

65 For a discussion on Vegetius' career in the imperial administration, see in particular *Epitoma rei militaris*, transl. Milner, pp. xxxv–xxxvi. Schöner, *Studien zu Vegetius*, proposed, from a 10th-century manuscript, the title of *comes sacrarum largitionum* (Count of the largesses, i.e. minister of finances). Milner prefers to think that a copyist's mistake altered the authentic reading *comes stabuli*. No definitive argument concerning his title of *comes* has been so far established. For further information(s) on the *Epitoma rei militaris* and its reception in the Middle Ages, see Richardot, *Végèce et la culture militaire* and Allmand, *The* De Re Militari *of Vegetius*.

Vegetius' *Epitoma rei militaris* also denotes that he possessed a good strategical and tactical knowledge. In any case, these treatises were intended for the same kind of audience as their writers or compilers; the authors were part of the imperial military aristocracy, mostly generals—high level officers—reaching right up to the emperor himself. Here we recall again the words of Constantine VII to his son: tactical treatises formed a corpus of material essential to the military elite in the Byzantine empire.[66] Tactical treatises were therefore often compiled in manuscripts in conjunction with ancient technical military treatises. No doubt convenience acted as a reason for such a common practice, as well as a simple need for a general to have an essential part of the military knowledge to hand. Military manuals were written in Greek at least from the *Strategikon* on, which represents, therefore, a *terminus ante quem* for the appearance of Greek language in Byzantine military literature and from the 6th century onwards, it gradually came to constitute the common language of the Byzantine military elite.[67] By the 10th century, Greek had become the language of the military elite almost everywhere in the Empire. We do have some information related to our subject, however, that suggests that Latin was still read and understood in the higher echelons in Constantinople: the authors of tactical treatises often refer to ancient tacticians such as Ammianus Marcellinus or Vegetius,[68] i.e. Latin-writing authors. Although these ancient authors may have been translated during the Byzantine period, references in the treatises point to a certain level of understanding among the military elite. All the manuscripts containing treatises for which the authors have been identified, were copied in Constantinople, making the city the most important centre for the transcription of this type of manuscript. Indeed, we still have no evidence of province-made manuscripts of military manuals.

### 3.2 *Body Armour Construction*

Armour design was an essential feature of Byzantine weaponry. Of the three major types of body armour that were used in the late Roman armies, i.e. the scale, lamellar and mail, all survived until the end of the Byzantine empire.

66 See p. 431–2 above.

67 The military aristocracy from the eastern part of the empire grew substantially from the 6th century onwards, which constituted a formidable catalyst for the spread of Greek in the Constantinopolitan ambience. From our corpus, only the *Epitoma rei militaris* was written in Latin. See Mihăescu, "Les éléments latins," pp. 481–98 and Mihăescu, "Les termes de commandements militaires latins," pp. 261–72.

68 See Dain, "Les stratégistes byzantins," pp. 319–40 for a study of the corpus of ancient authors and Haldon, *A Critical Commentary*, pp. 16–17. See also *Taktika*, VI.25, ed. Dennis; Heron of Byzantium, *Parangelmata poliorcetica*, 1–3, ed. Sullivan.

Again several terms were used by authors to designate scale, lamellar or mail armour without necessarily identifying them. However, the widespread use of such terms combined with valuable archaeological and iconographical data permits a more accurate image of their evolution. Chain mail was undoubtedly less frequently used than the other two types. Until the late Byzantine period, it was often limited to the protection of the articulations of some soldiers, sometimes their head and neck. Treatises employ the term *zaba* (ζάβα) to refer to these small mailed protections. In the treatises, the *zabai* are found among heavily armoured cavalrymen's armament but, with a few exceptions, they do not seem to have been a common object in manuscript miniatures (Fig. 12.3).[69]

It seems their use was almost exclusively reserved for cavalrymen and high officers. The mail demanded highly skilled and costly craftsmanship since the rings could be made only from authentic metallic material. Mail was currently used by late Roman cavalry, but fell into disuse in favour of scale or lamellar, i.e. splint armour.[70] It has been debated whether the term *lorikion* also designated chain mail armour. T. Kolias and J. Haldon hold this view, while T. Dawson favours a more generic meaning for the term, suggesting that it could also designate scale armour.[71] The *Taktika* recommends:

> Body armor (λωρίκια) down to the ankles that can be caught up with straps and rings, as well as leather carrying cases for them. If possible, the

69 *Praecepta militaria*, III.4, ed. McGeer. See also Kolias, *Byzantinische Waffen*, pp. 37–43. Grotowski, *Arms and Armour*, pp. 158–59 and n. 135 has seriously challenged the mail nature of *zabai*, especially because of their absence of the Madrid Skylitzes. Although fewly represented, this type of protections is not entirely absent from Byzantine iconography before the 12th–13th centuries. Several soldiers are depicted wearing *zabai* in the Chludov psalter (Moscow, Gosudarstvennyj Istoričeskij Musej, Sobr. A.I. Chludova 129д, fols. 58r, 60r, 9th century CE), repeated in Kolias, *Byzantinische Waffen*, tab. VI.3, VII.1. Haldon, *A Critical Commentary*, pp. 185–86 is in favour of zabai being quite the same as lorikia, i.e. mail, scale or lamellar long coats. Only two coats of mail—probably ceremonial coats—were recovered, both from the 10th century. See D'Amato, *Byzantine Imperial Guardsmen*, p. 56 and Jankovič, "Implements and Weapons," p. 60 and tab. V, 17 respectively.

70 Dixon/Southern, *The Roman Cavalry*, pp. 36–38; Bishop/Coulston, *Roman Military Equipment*, pp. 85, 117, 141 and 145.

71 Haldon, "Some aspects of Byzantine Military Technology," pp. 18–20 and 24–26; Haldon, *Warfare, state and society*, pp. 130–31; Kolias, *Byzantinische Waffen*, p. 37; Dawson, "Suntagma Hoplon," p. 86, n. 50 et p. 89, n.73.



FIGURE 12.3 Digenes Akritas fighting the dragon on a ceramic bowl

> armor should be made completely of chain mail (πάντα ἁλυσιδωτά), but if not, some of it may be of horn or dry cowhide.[72]

If materials such as horn or cow hide were substituted, then a *lorikion* might be exclusively a coat of mail.[73] It must have been more of a generic term to designate body armour, either mail or scale. As chain mail became less popular, splint armour (scale or lamellar) grew in popularity in the early Byzantine army. Scale armour is the most represented of the two, especially in manuscript miniatures, whereas the warrior saints provide more detailed representations that favour lamellar. Scale armour was already commonly used by late

72 *Taktika*, V, 19–21, ed. Dennis. The expression "πάντα ἁλυσιδωτά" does not necessarily refer to chain mail but to metal. It could then not even mean chain mail at all here, just metal scale-made armour.

73 Leather or boiled leather could also be used as substitution materials, boiled leather being the most effective but taking the greatest time to produce.

Roman armies and known as *lorica squamata*.[74] References to *lorikia* in military treatises and many representations indicate that the Byzantines wore it as a protective shirt, since chain mail came only with short sleeves.[75] Scales were attached by small thongs on the top and on one side; its flexibility was one of its advantages. Except the *lorikion*, another term has been identified as referring either to scale or lamellar: *klibanion*. Its increasing use can certainly be linked to increasing contact with peoples of the Eurasian steppes, who had already employed it for some time, but its precise origin remains uncertain.[76] There is no mention of it before the 9th century in Byzantine writings, yet lamellar is very likely to have been used earlier by the Byzantine army. The term is almost exclusively employed in military treatises, while other sources use generic expressions such as *thorax*.[77] It is designated essentially as a lamellar breastplate but with time it extended to the full upper body armour made of lamellae and scale or mail. Lamellar armour saw significant developments in the Byzantine period. As scale armour, it could be made of metal, or metal for which organic materials might have been substituted, but was much less

74 See Kolias, *Byzantinische Waffen*, pp. 38–40; Grotowski, *Arms and armour*, pp. 137–38 and n. 57; Gorelik, "Arms and Armour," pp. 134–35. Two major centers of influence are related to Roman and early Byzantine scale armour: Zygulski, *Bron starozytna*, p. 79 favours an Etruscan origin while Grotowski, *Arms and armour*, p. 134 points out its strong oriental influences, especially Parthian. See also Bishop/Coulston, *Roman Military Equipment*, pp. 85, 117 and 141.

75 *Taktika*, V.3; VI.2, ed. Dennis; *Praecepta militaria*, IV.2, ed. McGeer; *Sylloge Tacticorum*, XXXVIII.7; XXXIX.1, 6, ed. Dain. Bruhn Hoffmeyer, *Military Equipment*, pp. 55–60 differenciates two types of lamellar armour: an "oriental" type with long narrow sleeves and an "hellenistic" type, shorter and larger than its oriental counterpart. Byzantine lamellar armour would resemble the "hellenistic" type.

76 The origins of the term remain unclear. Wojnowski, "Periodic Revival," p. 211 indicates two possible origins, the Persian term *griwban* or the Latin *clibanium*. The second could well have derived from the first. See also Khorasani, "Linguistic Terms," p. 160 and Bivar, "Cavalry Equipment," pp. 277–78, 281. Nomadic auxiliaries from the imperial Roman army wore such armour, but its popularity grew in importance in the early Byzantine period.

77 See notably *Taktika*, V.3; VI.4, ed. Dennis; *Sylloge Tacticorum*, XXXVII; XXXIX, 6, ed. Dain; *Praecepta militaria*, II.3; III.4; IV.1, 2, ed. McGeer. *Digenes Akritas* also uses the term, together with *lorikion*, which would then designate scale armour. See *Digenes Akritas*, v. 277; 579, ed. Jeffreys. The term *manduas* could have refered to leather-made lamellar armour before the 9th century, yet no specific term seems to have designated lamellar in general. See Grotowski, *Arms and armour*, p. 128, n. 10, and pp. 155–57, especially n. 123 and 133. The absence of *klibanion* in the *Suda* is quite surprising, as noted by Grotowski. It could be explained either by its absence of the *Suda*'s sources or its high technical nature, yet no conclusive argument can be made here.

flexible than scale due to lamellae disposition. Lamellae were pointed upward and were attached along the bottom from left to right, originally to avoid bow strings interfering with the armour. In the second half of the 10th century, lamellae no longer overlapped but were first attached to a leather mount, making the lamellae more flexible and more resistant to blunt weapons.[78] This innovation rendered the armour a more lengthy item to make, but which nevertheless demanded far less skill to produce than chain mail and was much more resistant to damage from blunt instruments. Representations often show this type of body armour combined with small scale parts for articulations. Because of its undeniable advantages the lamellar armour was still in use with Byzantine troops in the 15th century. Lamellar armour represents in its evolutionary aspects one of the best and most significant features of what the Byzantine science of warfare had to offer.

### 3.3 *Lance, Bow and Sword: a Tactical and Technical Approach*

The omnipresence of bow and lance in the Byzantine soldier's armament and the innovations to which they were linked, whether technical or tactical, deserve our attention in this chapter. These two almost antagonistic weapons are representative of the evolution of Byzantine science of warfare, mostly from a tactical point of view. About the training of the Byzantine soldier around the end of the 6th century, pseudo-Maurice's *Strategikon* says:

> He should be trained to shoot rapidly on foot, either in the Roman or the Persian manner. Speed is important in shaking the arrow loose and discharging it with force. This is essential and should also be practiced while mounted. In fact, even when the arrow is well aimed, firing slowly is useless. He should practice shooting rapidly on foot from a certain distance

78 For the overlapping lamellae armour, see Dawson, "Kremasmata, Kabadion, Klivanion," pp. 44–47; Nickel, "The Mutual Influence," p. 109 and Tsurtsumia, "The Evolution of Splint Armour," pp. 71–72. On this new 10th-century armour construction, see Dawson, *ibidem*, pp. 44–50; Haldon, *Warfare, state and society*, p. 134 and Tsurtsumia, *ibidem*, p. 73. Also, leather thongs could be intertwined between each layer of lamellae. Only M. Parani has a different opinion, excluding any mount for the lamellae, considering the additional layer between each set of lamellae on representations as being simply shadows. See Parani, *Reconstructing the reality of images*, p. 107. This is very unlikely given the precision of some ivory, steatite or even painted icons representing such armour. Archaeological data concerning Byzantine scale or lamellar armour remains scarce: only a few lamellae were recovered in the Great Palace of Constantinople, that can be be defined without doubt as "Byzantine." See Brett/Macaulay/Stevenson, *The Great Palace of the Byzantine Emperors*, p. 99 and Beatson, "Byzantine Lamellar Armour," pp. 3–8.

> at a spear or some other target. He should also shoot rapidly mounted on his horse at a run, to the front, the rear, the right, the left. He should practice leaping onto the horse. On horseback at a run he should fire one or two arrows rapidly and put the strung bow in its case, if it is wide enough, or in a half-case designed for this purpose, and then he should grab the spear which he has been carrying on his back. With the strung bow in its case, he should hold the spear in his hand, then quickly replace it on his back, and grab the bow. It is a good idea for the soldiers to practice all this while mounted, on the march in their own country. For such exercises do not interfere with marching and do not wear out the horses.[79]

This type of training, linking bow and lance almost naturally, is significantly innovative for the time. The expression εἴτε Ῥωμαϊστὶ εἴτε Περσιστί designates the two main techniques for drawing the bow. The "Persian" manner, also called Mediterranean drawing, uses the three middle fingers to draw the string to the chest or the chin; it was used by Persians and Romans until the first century CE Romans and Byzantines also used the "Roman" manner, also called Hunnic or Mongol, employing the thumb and the forefinger to draw the string; it was the preferred technique of the Steppe and Ural-Altaic people, adopted many years previously.[80] It is no coincidence that the *Strategikon* recommends this type of training, not for any soldier but specifically for a cavalryman, and even though the *Strategikon* does not mention it, it is clear that this training follows a specific pattern. Although not explicitly cited by the author, the model used here is that of a warrior native to the Steppe: in other words, an excellent, versatile mounted warrior. However, it acted very well as a model for the training of Byzantine soldiers. In Procopius' time (d. *c.* 554) it already seems to have been successfully in place and its presence is recorded in texts during Maurice's reign (582–602).[81] Bows were of the composite reflex type and lances were then of average length, "of the Avar type with leather thongs in the middle of the shaft

79 *Strategikon*, I.1, ed. Dennis/Gamillscheg. The training of the soldier is repeated almost identically in the *Taktika*, VII.3–4, ed. Dennis. However the *Taktika* distinguishes between the training of different types of soldier; Vegetius' *Epitoma rei militaris*, while being long-winded on the subject, does not mention it.

80 For an extended discussion of shooting techniques in Byzantium, see Bivar, "Cavalry equipment and tactics," p. 285; Kolias, *Byzantinische Waffen*, pp. 233–38. On the introduction of the Hunnic/Mongol shooting in Roman-Byzantine army, see James, "Dura-Europos," pp. 77–84.

81 See Koehn, "Justinian's Wonder Warriors."

and with pennons."[82] The Avars, as well as other people native to the Steppe, formed a source of inspiration for the Byzantine science of warfare, especially cavalry warfare. By the 9th–10th century, however, this type of soldier clearly failed to develop in the Byzantine empire. Military treatises introduced a cavalry that was much more diversified, more specialized. Mounted archery, a highly skilled and practice-demanding discipline, had gone into decline,[83] and a well-known hybrid cavalry formation known as the *kataphraktoi* formation emerged around the middle of the 10th century. The *Praecepta Militaria* indicated the position of the archer in this formation:

> There must be archers with the *kataphraktoi*, in the middle where they can be protected by them. The men in the first, second, third, and fourth lines should not be archers, but from the fifth row on back to the rear. If the total number of *kataphraktoi* in the formation is 504, they must include 150 archers. If it is 384, they must include eighty archers.[84]

Soldiers were arranged in the form of a wedge advanced towards the enemy, with mounted archers in the centre backing lancers and melee cavalrymen.

By the 12th century CE, another fighting technique was developed in Byzantium: the couched lance. Whether or not its appearance was linked to contacts with the Normans has been the subject of discussion in several studies but again no conclusions have been arrived at. The first mention of this technique in Byzantium was in fact in the illustrations in a Constantinopolitan manuscript from the mid-11th century (Fig. 12.4). Treatises do not mention it before that date, and historical accounts like Nicetas Choniates' *History* and Anna Komnena's *Alexiad* mention its use by the Byzantines. It was, however, a method that remained very discrete and does not seem to have gained much popularity.[85] By the 12th century onwards, references to mounted archery in

82 *Strategikon*, I.2, ed. Dennis/Gamillscheg. The *Taktika* and the *Sylloge Tacticorum* mention lances 8 *peicha* long—c. 3.70 m—but refer at the same time to them as "short cavalry lances" that also can be thrown. See *Taktika*, V, 2, 12; VI, 6, 34–35, ed. Dennis; *Sylloge Tacticorum*, XXXVIII.3; XXXIX.1, ed. Dain.

83 *Taktika*, VI.5–6, ed. Dennis, and also Haldon, *A Critical Commentary*, pp. 160–62.

84 *Praecepta militaria*, III.6, ed. McGeer; also in *Taktika*, 60.6, ed. McGeer.

85 See notably the *Alexiad*'s description of Euphorbenos Constantine Katakalon's son Nikephoros: "On this occasion this man's son Nicephorus (who later became the husband of my younger sister Maria Porphyrogenita) wielding a long spear turned round sharply to face the Scythian who was pursuing him, and struck him in the chest, whereupon the latter straightway fell down dead. For of a sooth he knew how to brandish a spear and



FIGURE 12.4 Byzantine cavalrymen using the couched lance technique

the Byzantine army were almost exclusively associated with nomadic or semi-nomadic recruits while Frankish mercenaries fought with the couched lance. It is still not clear whether tactical innovations forced the Byzantines to change their fighting techniques and their choice of weaponry or whether it was the other way around. What is certain is that use of bow and lance in cavalry warfare had evolved considerably and had moved to more specialized troops. Tactically, the versatile Byzantine Steppe-like cavalryman had disappeared.[86]

cover himself with a shield; and anyone seeing him ride, would have conjectured that he was not a Roman but had come from Normandy," Anna Komnena, *The Alexiad*, *Medieval Sourcebook: Alexiad—complete text* (online: <https://sourcebooks.fordham.edu/basis/AnnaComnena-Alexiad00.asp>), X, 3, transl. Dawes. See also Niketas Choniates, *Historia*, p. 17, ed. Van Dieten who employs the term "ἱππομαχία καὶ δοράτων ἀγκοινήσει" to designate the technique of the couched lance.

86 In the beginning ot the 12th century, Nikephoros Bryennios describes the training of Alexios I Komnenos' sons John and Isaac: "To arm oneself skillfully, to protect oneself with an oblong shield against enemies' arrows, to brandish a spear, to ride a horse dexterously, to hit the target with a bow, and to know how to line up a battle-array, place an ambush, take up a position in fit time, or to build a palisaded camp." (ed. Gautier,

The best-known Byzantine edged weapon remains the double-edged sword, known as s*patha/spathion* (σπάθα/σπαθίον). Another term, *xiphos* (ξίφος), is widely used in Byzantine military manuals and histories to refer to the sword. This seems to be a generic term, whereas, at least in the early Byzantine period, *spathion* seems to have designated the long sword.[87] Directly inherited from the Germanic long cavalry sword, it could have been adopted by the Roman army as early as the 3rd century CE or after the battle of Adrianople in 378.[88] Its length, c. 70–80 cm, permitted greater projection, which was a major asset in cavalry or combat fighting. According to the *Sylloge Tacticorum*, the *spathion* should be no less than 4 *spithame* long (c. 93 cm); whether this measurement includes or excludes the hilt of the sword has been widely debated.[89] Nevertheless, the sword seems to have gained in length by the 10th century, though we cannot be precise about the exact date or cause of its gain in length. Several pieces dated to the middle Byzantine era were recovered within territory formerly under imperial control. But their identification as "Byzantine" remains a problem, and V. Yotov notes that "we should individuate the concept of "Byzantine" swords: not all the swords used inside the Byzantine army were used by authentic Byzantine soldiers (many mercenaries, like the Varangians, employed their swords in service) but the swords were effectively produced by Roman manufactories."[90] In spite of this, precise typological elements have been established. These are based mostly on the design of sword guards, though blade measurements were also taken into account, within which four major groups have been established: the Aradac-Kölked-Corinth type, the Garabonc

p. 75.17–22) Coufalová, "The noble illustrious warrior," p. 8. Byzantine military aristocracy was an essential part of Byzantine cavalry and commanders, but was not representative of all the cavalrymen and their training where shooting with bows did not reflect tactical use of mounted archers.

87 Vegetius mentions it as a "gladios maiores," *Epitoma rei militaris*, 2.15, ed. Reeve.

88 See Bruhn Hoffmeyer, *Military Equipment*, pp. 101, 117; Kolias, *Byzantinische Waffen*, pp. 136–37; Dixon/Southern, *The Roman Cavalry*, p. 103; Grotowski, *Arms and armour*, pp. 342–44.

89 *Sylloge Tacticorum*, XXXIX.2, ed. Dain. The treatise also indicates that the *paramerion* (*παραμήριον*), another edged weapon, should be of the same length, see *Sylloge Tacticorum*, XXXVIII.5, ed. Dain. The *paramerion* will be discussed below. The unit of measurement employed most probably was the *spithame basilike* (c. 23.4 cm). Kolias, *Byzantinische Waffen*, p. 137 thinks of a 16 cm hilt for the *spathion*, whereas Ravegnani, *Soldati di Bisanzio*, p. 45 has wider estimation: between 81 and 94 cm for the blade and between 12 and 14.5 cm. See also Haldon, "Byzantine military technology," p. 31 and Grotowski, *Arms and armour*, pp. 344–45 and n. 134 & 135.

90 Yotov, "A New Byzantine Type of Sword," p. 115.

type, the Kunágota type and the Pliska type.[91] Most of the sword pieces belonging to these types have been found in the western part of the empire. Findings from a shipwreck near Serçe Limanı (on the southern coast of Turkey), including a bronze sword hilt, have revealed that the weapons almost certainly originated from southeastern Bulgaria.[92] We can say with certainty that exchange networks relating Byzantium to the East played a major role in the circulation of military technologies, but as yet we have little substantial information about those technologies. The small number of findings—so far a dozen swords have been associated with this model—leaves an unsolved problem. Furthermore, they do not allow us to assess the exact role played by the double-edged sword in the Byzantine military, and though the sword was widely used in the Byzantine military it clearly remained a secondary weapon in their eyes. This situation changed in the 10th century with the appearance of a tactical innovation within the cavalry: the *kataphraktoi* (*καταφράκτοι*) formation. This innovation can be linked to the use of a new weapon: the *paramerion* (*παραμήριον*). The *Praecepta Militaria* provides the following formation:

> The *kataphraktoi* should have the following weapons: iron maces with all-iron heads—the heads must have sharp corners and be three-cornered, four-cornered, or six-cornered—or else other iron maces or sabres. All of them must have swords. They should hold their iron maces and sabres in their hands and have other iron maces either on their belts or saddles. The first line, that is, the front formation, the second, third, and fourth lines must have the same complement, but from the fifth line on back the *kataphraktoi* on the flanks should set up like this—one man armed with a lance and one armed with a mace or else one of the men carrying a sabre, and so they should be all the way to the back line.[93]

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91 See in particular Weinberg, "A wandering soldier's," pp. 516–19; Yotov, "Byzantine Time Swords," pp. 35–42; Yotov, "A New Byzantine Type of Sword," pp. 113–24. Bruhn Hoffmeyer, *Military Equipment*, pp. 98–102 and 130 tried to establish a typology of Byzantine weapons according to the Madrid Skylitzes. See also Dawson, *Byzantine Infantryman*, p. 28. Some of the types they identified have been verified by archaeological findings though the others cannot be considered as entirely reliable, given that some pieces of Byzantine art constitute their only source.

92 See Bass/Matthews/Steffy et al., *Serçe Limanı*, pp. 385–86. The 11th century bronze sword hilt belongs to the Kunágota type identified by V. Yotov. Its decoration elements indicate a strong Indian influence.

93 *Pracepta Militaria*, III.7, ed. McGeer; also in *Taktika*, 60.7, ed. Dennis. The *paramerion* is also present as a primary weapon in *Sylloge Tacticorum*, XXX.2, XXXVIII.5, 7, 10, XXXIX.2, 9, ed. Dain.

It is no coincidence that this extract serves to place the *paramerion* in the forefront as a main weapon of the *kataphraktoi* and its appearance in this cavalry formation can be linked to the nature of the weapon itself. The *paramerion* has been an important object of discussion within studies of Byzantine weaponry for many years. The first notable occurrence can be found in the *Taktika*:

> *Parameria*, large single-edged blades/swords[94]

*Paramerion* or its plural are found subsequently on several occasions in tactical treatises up to the 11th century, when it completely disappears. These allusions suggest a single-edged weapon, resembling a long *machaira*. The *paramerion* was first identified as a sabre but in the absence of both material and visual evidence this hypothesis was rendered very unlikely. Consequently, little doubt remains that the 9th–10th century *paramerion* was a *palash*, a single-bladed straight sword or proto-sabre.[95] It is not surprising that no information can be found on the curve of the blade. Indeed it seems that since we can find no mention of its appearance, the sabre was not suddenly introduced into Byzantium. The Byzantines most probably developed this sword themselves or adopted it as a development of the *palash* over a period of time . No archaeological specimens can be related with certainty to Byzantine craftsmanship, though swords like the *palash* were found in Malaya Pereščepina (Ukraine, 7th century) and are strongly associated with Byzantine manufacture.[96] The *paramerion* was worn slung from a waistbelt, i.e. not in the "Roman manner" and placed on the

94 Haldon, *A Critical Commentary*, p. 173. This translation of the passage "παραμήρια, μαχαίρας μεγάλας μονοστόμους," more accurate, was preferred to the one in Dennis' edition of the *Taktika*, see *Taktika*, V.2, ed. Dennis. It is also described in a similar manner in the following chapter of the treatise: "ἔχειν δὲ καὶ σπαθία ἀποκρεμάμενα τῶν ὤμων αὐτῶν κατὰ τὴν Ῥωμαϊκὴν τάξιν, καὶ ἕτερα παραμήρια ἤτοι μαχαίρας διεζωσμένους."; see *Taktika*, VI.2, ed. Dennis. The *Taktika* is not the first source that mentions the *paramerion*. It was already cited in the *novellae* of Justinian I (527–565), see Kroll/Schöll, *Corpus iuris civilis*, p. 416. The *paramerion* from the novellae may well have been more than a ceremonial sword as it is cited with other non-ceremonial weapons.

95 No sabre was found within the territory of the empire and no representations can be clearly linked to the sabre before the 13–14th centuries; see Kolias, *Byzantinische Waffen*, p. 145. The identification of the *paramerion* as being a *palash*, at least in the middle Byzantine period, is shared by Haldon, *A Critical Commentary*, pp. 173–74; Grotowski, *Arms and armour*, p. 359; Kolias, *Byzantinische Waffen*, pp. 137–38. Some *palashes* had the a slightly curved blade and/or a two-edged point, those could have been features of the *paramerion* as well.

96 Kolias, *Byzantinische Waffen*, p. 138; Lebedynsky, *De l'épée scythe au sabre mongol*, p. 155.

thigh (hence the term *para merion*). A long, single-edged sword, together with maces, was an almost perfect weapon for melee cavalrymen. They allowed the fighter sufficient reach either to slash or thrust at any type of foe, thus leaving the possibility for a great deal of versatility within fighting styles. The appearance of the *palash* is linked generally to the development of cavalry melee techniques including those of Byzantium. Its presence in a hybrid formation, regrouping archers, lancers and proper heavy-armed melee cavalrymen, serves to reinforce this connection, and underlines the growing importance of melee combat in the Byzantine science of warfare.

### 3.4 *Stirrups and Saddles*

Stirrups and saddles were also significant in the development of cavalry warfare in the Byzantine empire, and became one of the major foci of Byzantine science of warfare. The first mention of the stirrup in Byzantium dates back to the 6th century CE in the *Strategikon* and probably appeared in the area around the imperial territory at about the same time; here it is designated as a *skala*.[97] Several stirrups from the 6th–7th centuries were recovered from archaeological sites in the ancient Justiniana Prima, now Caričin Grad (Jablanica, Serbia) and Kunágota (Bénés, Hungary).[98] Whether these stirrups are of Byzantine manufacture or even representative of "Byzantine" craftsmanship is still under debate and is linked to the question of the exact nature of the stirrups found in the archaeological sites. They are so thin that no mounted archer would have been able to stand upon them, especially in smooth cavalry boots. However, such stirrups could, when needed, easily maintain the rider's feet and be used, in addition to the reins, as directional tool.[99] The word *skala* has also been debated, especially the origins of the term, and there seems to remain little doubt that it comes, as S. Lazaris has demonstrated, from the Latin.[100] The *Strategikon* makes it clear that the *skala* is not of Avar origin like other equipment cited by the author. It could have reached Byzantium a little earlier than the

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97 *Strategikon*, I, 2, 2, ed. Dennis/Gamillscheg. See also the term repeated in the *Taktika*, VI, 10, 49, ed. Dennis.

98 For the Caričin Grad stirrups, see Ivanišević, "Caričin Grad," p. 25 and figs. 20–2; for the Kunágota stirrups, see Yotov, "The Kunágota Sword-Guard," p. 116, figs. 2.3–4 and 8–9.

99 For a discussion on the nature of these stirrups and the appearance of the "Byzantine" stirrup in general, see Bivar, "Cavalry equipment and tactics," pp. 61–68, White Jr., *Medieval Technology and Social Change*, pp. 10–19; Lazaris, "Considérations sur l'apparition de l'étrier," pp. 275–88; Ivanišević/Bugarski, "Les étriers byzantins," pp. 135–42 and Kraft, "Lat.—griech. SCALA," pp. 155–92. For the use of stirrups as directional tools for the rider, see Gillmor, "Practical Chivalry," pp. 14–15.

100 Lazaris, "Considérations sur l'apparition de l'étrier," pp. 277–78.

Avars or developed within the empire; several centres of innovation cannot be excluded given the evidence we possess today. Later on in the middle Byzantine period the stirrup was designated as *anaboleus* (ἀναβολεύς). From the 7th century onwards stirrups are regularly depicted in Byzantine art though it had considerably evolved from its early design. In the middle Byzantine period, it became triangular with a small floor, suggesting the Byzantine interest in developing horse riding and cavalry. As noted by Nicole Thierry, the stirrup with a broad base seems to have been brought in by the Turks.[101] Byzantine cavalrymen also rode *a la jinete*, i.e. with short stirrups and relatively little enveloping saddles—allowing greater control of the horse and greater manoeuvrability. There is a combination of the two features in Byzantine representations of the couched lance technique. An important innovation took place in the early Byzantine period: the introduction of the high saddle, probably of Avar origin, in the place of the soft Roman saddle.[102] It greatly helped the horseman to remain stable and the wooden frame distributed the rider's weight on the back of the horse. The Byzantine saddle was known as *sella* (σέλλα), a term of Latin origin, but no distinction between the different types of saddle can be discerned from the sources.[103] No archaeological data is available for Byzantine saddles or even projected ones but in this case precise representations provide valuable help. Different types of saddle appear in the period from the 4th/6th to the 14th centuries CE, some having a small pommel and cantle or alternatively a high pommel and cantle. In any case, as Kekaumenos comments, cavalry saddles could not be excessively large.[104] Although no innovation in saddle construction can be datable with precision in relation to Byzantium, many enveloping saddles, probably of western origin, appear in Byzantine art at the end of the 12th and the beginning of the 13th century.

## 5 Conclusion

The situation described by Vegetius at the end of the 4th century remained more or less the same throughout the whole Byzantine period. From its

101 Thierry, "Portraits funéraires inédits," p. 172. See also Digard, "Les cultures équestres," pp. 25–29 for further information on eastern equestrian cultures and saddle development.

102 On the Roman soft "horned" saddle, see Hyland, *The Medieval Warhorse*, pp. 5–7; Gawronski, "Roman Military Saddle," pp. 31–40.

103 For further information on the Latin *sella*, see Mihăescu, "Les éléments latins," pp. 481–98.

104 Kekaumenos, *Strategikon*, 2.59, ed. Spadaro.

beginning to its end, Byzantium and its armies had to face enemies that surpassed it in numbers or in strength and fighting capability. Although surrounded by such enemies, it managed to resist or even sometimes to regain territorial control by the same means that Vegetius mentions. To deal with these threatening foes, they had to persistently focus on improvements and developments in military affairs. They displayed these developments in military treatises—either purely poliorcetical or tactical—which combined something more than classical theoretical knowledge but offered patterns for application in the field. This knowledge derived from theory and practice, and the amalgam of the two rendered the treatises valuable manuals. The teaching and recommendation contained in them, as much as the military equipment itself, accounts for the ability of the Byzantine military to constantly adapt. In order to survive, the Byzantines were persistently trying to take a lead in science of warfare as a way of compensating for their weaknesses. But the science of warfare alone was not enough.

CHAPTER 13

# The Occult Sciences in Byzantium

*Maria K. Papathanassiou*

By the term "Occult Sciences" we mean theories and practices that do not belong to any domain of modern "Science" because they do not use measurable quantities and their principles are not based upon mathematical formulae. Occult sciences embrace theories, beliefs, and activities or practices related to the irrational inner self and thus the criteria of modern science cannot be applied to them. Their theoretical basis is the Stoic principle of cosmic sympathy-antipathy between different parts of the world and the correspondence between macrocosm and microcosm.

The Stoics considered the cosmos as a perfect living body filled with an all-pervading substratum called pneuma and composed of a mixture of air and fire. A specific physical property of pneuma is the tension (τόνος) that generates the cohesion of matter and the contact between all parts of the cosmos. These parts cannot function by themselves, and they always depend on the whole cosmos and its other parts. The pneuma, making the whole cosmos coherent and interactive (συμπαθές), unifies all its parts and makes one nature. Consequently, any action or activity in a part of the cosmos influences all its other parts. Moreover, as pneuma permeates the human body to its tiniest parts and becomes its soul, in the same way, this pneuma, identified with God, penetrates all parts of the cosmos and becomes its soul.

Among occult sciences, only astrology and alchemy are considered as precursors of modern sciences of astronomy and chemistry. In Astrology the principle of cosmic sympathy correlates the parts of the Mega-cosmos (fixed stars, planets, zodiacal signs) with the parts of the Micro-cosmos (man) and the casting of horoscopes requires a high technical level of astronomical calculation. Alchemy also adopted the Stoic doctrine that Nature is One and the Whole (cosmos) coherent and interacting, due to the all-pervading pneuma; thus, it became a basic principle in the theory and practices regarding the fundamental qualities of matter and aimed to transform matter, especially metals to silver and gold.

As far as Divination is concerned, the Stoics included it in their epistemological beliefs. In his book "*Physics of the Stoics*," Sambursky exams extensively those beliefs referring them to modern science. The Stoics believed in "artificial divination" from inferences based on signs and events in their physical

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surroundings, stemmed from their attitude towards "natural divination," which was the faculty of inspired persons to foresee the future.[1] The artificial or inductive divination became of great importance in their epistemology and, as can be seen in his work *On Divination*, influenced Cicero greatly. The Stoics regarded divination as a "science, based on observation and interpretation" or, as "art based on the evidence of certain results."[2] They did not distinguish "in principle between divination and science as both deal with the forecasting of determined events," and "every discrepancy which becomes apparent post factum has to be attributed to the inadequacies of the experts or the imperfection of their methods."[3]

The Stoics were interested both theoretically and scientifically in the problem of divination because "they had to accept the validity of divination in a deterministic world and at the same time saw in it a confirmation of determinism by inductive inference."[4] Alexander of Aphrodisias quoted the Stoic definition of the possible: "The possible event is something that is not prevented by anything from happening even if it does not happen." Sambursky says that "The Stoic conception of the possible as arising from human ignorance of the future in a deterministic world, on the one hand led to a deeper comprehension of causality, and on the other clarified for the first time the problem of disjunctive propositions containing statements subject to empirical verification."[5]

In terms of modern science, Sambursky concludes that the Stoics: "Instead of seeing causation as a one-dimensional chain of actual occurrences they saw it as a many-dimensional network of potential occurrences, all of them equal possibilities fitting within the frame of "fate," out of which, and in accordance with the rules of disjunction, only one course will be actualized."[6] Moreover, "for the first time in Greek science, [the Stoics] introduced the symmetrical

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1 Sambursky, *Physics of the Stoics*, p. 66.

2 Sambursky, *Physics of the Stoics*, p. 67. Sextus Empiricus, *Adversus Mathematicos*, IX, 132: εἰ μὴ εἰσὶ θεοί, οὐδὲ μαντικὴ ὑπάρχει, ἐπιστήμη οὖσα θεωρητικὴ καὶ ἐξηγητικὴ τῶν ὑπὸ θεῶν ἀνθρώποις διδομένων σημείων, οὐδὲ μὴν θεοληπτικὴ καὶ ἀστρομαντική, οὐ λογική, οὐχ ἡ δι᾽ ὀνείρων πρόρρησις. ἄτοπον δέ γε τοσοῦτο πλῆθος πραγμάτων ἀναιρεῖν πεπιστευμένων ἤδη παρὰ πᾶσιν ἀνθρώποις. εἰσὶν ἄρα θεοί. Diogenes Laertius, *Vitae philosophorum*, VII (*Zeno*), 149: καθ᾽ εἱμαρμένην δέ φασι τὰ πάντα γίνεσθαι Χρύσιππος ἐν τοῖς Περὶ εἱμαρμένης καὶ Ποσειδώνιος ... καὶ Ζήνων ... ἔστι δ᾽ εἱμαρμένη αἰτία τῶν ὄντων εἰρομένη ἢ λόγος καθ᾽ ὃν ὁ κόσμος διεξάγεται. Καὶ μὴν καὶ μαντικὴν ὑφεστάναι πᾶσάν φασιν, εἰ καὶ πρόνοιαν εἶναι· καὶ αὐτὴν καὶ τέχνην ἀποφαίνουσι διά τινας ἐκβάσεις, ὥς φησι Ζήνων τε καὶ Χρύσιππος ... καὶ Ἀθηνόδωρος καὶ Ποσειδώνιος...

3 Sambursky, *Physics of the Stoics*, p. 69.

4 Sambursky, *Physics of the Stoics*, p. 71.

5 Sambursky, *Physics of the Stoics*, p. 76, Alexander Aphrodisiensis, *De fato*, ed. Bruns, p. 176 ff.

6 Sambursky, *Physics of the Stoics*, p. 77.

concept of interaction between members of certain classes or structures."[7] Consequently, divination, an official institution and a public custom for long periods in antiquity, was a significant topic for scientific study by the Stoic philosophers and merited its place in the precursors of modern science.

In the last two centuries, occult sciences were studied by eminent scholars who accompanied their research with the publication of related Greek texts, for example, J.L. Ideler's edition of *Physici et medici graeci minores* (2 vols., 1848). M. Berthelot made a significant contribution to the study of early chemistry with the publication of his *Collection des anciens alchimistes grecs* (3 vols., 1887–88), *Introduction à l'étude de la chimie des anciens et du moyen âge* (1889), and *La chimie au moyen âge* (3 vols., 1893). A. Bouché-Leclercq studied divinatory practices in his *Histoire de la Divination dans l'Antiquité* (4 vols., 1879–82), and especially *L'Astrologie grecque* (1899). In the last century, L. Thorndike wrote *A History of Magic and Experimental Science* (8 vols., 1923–1958). In Greek bibliography Ph. Koukoulès revealed various magical practices among the Byzantines in his *Βυζαντινῶν βίος καὶ πολιτισμός* (6 vols., 1947–55). Furthermore, the *Papyri magicae graecae* (2 vols., 1928, 1931) by K. Preisendanz and their translation by H.D. Betz (1992), elucidated the use of spells and amulets in magical practices. During the last few decades, the critical editions of the works of Greek alchemists that appeared in the series "Alchimistes grecs" or in individual publications, contributed to the better understanding of Byzantine texts. Other scholars focussed their research on special topics (P. Magdalino, *L'Othodoxie des astrologues*, 2005), and published their papers in collective volumes, as for example *Byzantine Magic* (ed. H. Maguire, 1995) and *The Occult Sciences in Byzantium* (eds. P. Magdalino/M. Mavroudi, 2006).

## 1 Divination and Magic

### 1.1 *Divination*

It is well known that the early Christian Church opposed divinatory and magical practices. Nevertheless, old superstitious and mystical ideas were deeply rooted in the popular psyche and thinking. Consequently many of these activities survived throughout the Byzantine period. It is noteworthy that it was not only ordinary people who entertained such beliefs but also state and ecclesiastic officers, including emperors who endorsed occultism, by consulting diviners, and practicing magic. Our claims are based on primary sources drawn from the work of historians, chronographers, canon laws and patristic authors

7 Sambursky, *Physics of the Stoics*, p. 81.

regarding the various divinatory and magical practices employed from early antiquity. Here are some examples, drawn from the works of Byzantine chronographers and historians mentioned above:

According to the chronographers John Zonaras (*c.* 1074–*c.* 1159) and George Kedrenos (11th cen.), the sophists Libanios (314–394) and Iamblichos (*c.* 245–*c.* 325) employed alectoromancy to discover who would reign after Valens (364–78). They observed that the rooster ate only the grains on the letters Θ, E, O, and Δ; as a result, the emperor persecuted many men called Theodosios, Theodore, and Theodotos. Moreover, the ecclesiastic historian Socrates (*c.* 380–*c.* 450) reports that Valens had also been informed by necromancy that the initial letter of the name of his successor was Θ, so he condemned to death many men with that initial.[8]

The old belief that the souls of the dead were endowed with prophetic properties which provided men with warnings about their future was already known from Homer's *Odyssea* (Odyssey) XI and survived in late antiquity and into the Byzantine period. For example, Emperor Julian (360–63) contemplating his campaign against Persia demanded divinations and oracles.[9] In later centuries emperor Theophilos (829–42) favoured high-ranking officers involved in magical practices.[10]

According to Michael Attaleiates (*c.* 1022–80), the emperor Nikephoros Phocas (963–69) paid attention to the meaning of names (*kledones*). Thus during his expedition against Crete he rejected a place for the disembarkation of his army because of its unfavourable name Φυγέλλα (run away) and decided in favour of another site having a more favourable name Ἁγία (Saint, Sacred).[11]

8 Joannes Zonaras, *Epitome historiarum*, book 13, ed. Büttner-Wobst, p. 81, lines 3–16. Georgius Cedrenus, *Compedium historiarum*, ed. Bekker, p. 548, lines 14–22. In alectoromancy the diviner observes a rooster pecking the grains of wheat scattered in the shapes of the 24 letters of Greek alphabet on the ground. The letters left without grains show the name of the person putting the question. Socrates Scholasticus, *Historia ecclesiastica*, book 4, ch. 19, ed. Maraval/Périchon.

9 Theophanes, *Chronographia*, ed. de Boor, col. 52, lines 19–21: Ἰουλιανὸς πολλοὺς ἐν διαφόροις τόποις ἀπέστειλεν εἴς τε μαντείας καὶ χρηστήρια, ὅπως ἂν δόξῃ μετ' ἐπιτροπῆς τῶν δαιμόνων ἐπὶ Πέρσαις πόλεμον ἐγχειρεῖν.

10 *Theophanes continuatus*, book 4, ch. 8, ed. Bekker, col. 157, line 6.

11 Michael Attaleiates, *Historia*, ed. Pérez Martín, pp. 223–24, lines 10–24. Κληδὼν (pl. *κληδόνες*, kledones) means a special word or phrase that would indicate the future: Michael Glycas, *Annales*, ed. Bekker, col. 364, lines 6–12. Psellus, *Τίνα περὶ δαιμόνων δοξάζουσιν Ἕλληνες*, *Patrologia Graeca*, vol. 122, col. 880: Κληδὼν δέ ἐστι δαιμόνων πονηρῶν, ὡς καὶ αὐτὸ δηλοῖ τοὔνομα πρόσκλησις. Τελεῖται δὲ ἄρτι τρεπομένου πρὸς νότον ἡλίου, καὶ μειοῦντος μὲν ἡμέραν, τὴν νύκτα δὲ αὐξάνοντος. Theodore Balsamon describes the ritual of kledones practiced in the evening of 23 June (eve of the 24th, birthday of St Jean the Baptist) that

The 11th-century scholar Michael Psellos describes dish-divination or lecanomancy, the most common divinatory method in the Byzantine period. In this a dish was filled with common water which was then endowed with extraordinary power by the spells recited over it; the water received the mantic breath which produced noise and other confused sounds that are then interpreted by the diviner.[12] In the following century, Anna Komnena reported that her father Alexios I (1081–1118) was planning a campaign against the Cumans. He wrote on two pieces of paper two different questions. The first asked whether, to proceed, the other, whether to abandon the campaign. He then put them on the altar. After a vigil, the priest chose the pro-campaign paper. Alexios used the same method of kleromancy to decide between his campaign against Iconion or Philomelion.[13]

The prevalent belief in the prophetic property of dreams is also a very ancient one. In Greek mythology, Oneiros (dream) is a child of Night (the other two children being Sleep and Death) who serves as Zeus' messenger to sleeping mortals warning them of their future. In Greek medicine the divinatory dreams of patients played an essential part in the treatment prescribed by the priests-physicians in the famous healing temples of Asclepios in Epidaurus (NE Peloponnese) and the island of Kos. Particular works on the interpretation of dreams date back to antiquity and carry in later centuries. The most famous among them were the *Oneirocriticon* of Artemidoros of Ephesos (2nd century) and the *Achmetis Oneirocriticon* (10th century), together with those of the patriarchs Germanos (715–30) and Nikephoros (806–15), of ps.-Astramphychos, and one under the name of prophet Daniel. Although divination by interpretation of dreams was outlawed Byzantine emperors believed in their prophetic property and consulted relevant books in critical moments; for example, Leo

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survives until now in modern Greece: Koukoulès, *Βυζαντινῶν βίος καὶ πολιτισμός*, vol. 1.2, p. 172.

12 Psellos, *Τίνα περὶ δαιμόνων δοξάζουσιν Ἕλληνες*, *Patrologia Graeca*, vol. 122, col. 881: Καὶ λεκανομαντεία … κατῳκονόμηται ὑπὸ λεκάνης ὑποκειμένης καὶ μαντικοῦ πεπληρωμένης ὕδατος … Τοῦτο δὲ δαιμόνιόν ἐστι γεῶδες καὶ μερικὸν· καὶ ἐπειδὰν ἐμπέσῃ τῷ ὕδατι, πρῶτον μὲν ἦχόν τινα ἄσημον τοῖς περιεστηκόσι κατὰ τὴν ὑποδοχὴν ἐμποιεῖ, ἔπειτα δὲ ἐπικείμενον τῷ ὕδατι ἀμυδρούς τινας φθόγγους τῆς τοῦ μέλλοντος ὑποψοφεῖ προγνώσεως.

13 Anna Komnene, *Alexias*, book 15, ch. 4, §4. Kleromancy is a divinatory practice by casting lots, beans, cubes, astragaloi (dice). This is a practice used for the election of the abbot in the monasteries: the names of three candidates were written on three different pieces of paper and put on the altar in the evening. After the vigil and the liturgy of the next day, the priest or a little boy chose one out of the three papers on the altar; the candidate whose name was written on the chosen paper is elected as abbot.

VI the Wise (886–912) on the day of a battle advised his generals to spread the rumour that they had had dreams predicting victory.[14]

Other divinatory methods used the observation of geological and meteorological phenomena, such as thunder, lightning, and earthquakes, as well as the moon's path through the zodiacal signs. Moreover, there were many related divinatory works (i.e., seismologion, brontologion, selenodromion) that could be consulted by those who were interested in the subject.[15] Patriarch Photios also mentions the observation of clouds, reporting that a woman called Anthousa revealed to emperor Leo his future, as she had seen a cloud in human form being swallowed by another in the shape of a lion.[16] In addition, extraordinary astronomical phenomena such as the appearance of a comet and the eclipses of the sun and the moon predicted unfavourable facts.[17] Another old practice was the observation of the flight of birds (especially eagles, crows, owls, and roosters) most of which predicted unfavourable events.[18]

Finally, the polemics of the Fathers of the Church, the State legislation, the chronographers and the canon laws of Photios and Balsamon provide evidence that the old tradition of the study the entrails of sacrifices, especially hepatoscopy,[19] continued throughout the Byzantine period.[20]

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14 Leo VI Sapiens, *Tactica*, ch. 20, §§ 149, 179, ed. Dennis.

15 Koukoulès, *Βυζαντινῶν βίος καὶ πολιτισμός*, vol. 1.2, pp. 218–26.

16 Photios, *Biblioteca*, ed. Bekker, Codex 242, col. 340b, lines 13–16.23–36.

17 For example: Plutarchus, *Nicias*, ch. 23, §1–2; *Dion*, ch. 24, §1–3. J. Chrysostomi *De pseudoprophetis*, *Patrologia Graeca*, vol. 59, col. 563.

18 Synesii *De insomniis* (Συνεσίου *Περὶ ἐνυπνίων λόγος*), *Patrologia Graeca*, vol. 66, col. 1284: οὕτως ὁρῶσι σοφοὶ τὸ μέλλον, οἱ μὲν ἄστρα εἰδότες, ἄλλος τὰ μένοντα, καὶ ἄλλος τὰ πυρσὰ τὰ διάττοντα· οἱ δὲ ἐν σπλάχνοις αὐτὰ ἀναγνόντες· οἱ δὲ ἐν ὀρνίθων κλαγγαῖς, καὶ καθέδραις, καὶ πτήσεσι. *Sapientissimi Pselli expositio in Oracula Chaldaica* (*Τοῦ σοφωτάτου Ψελλοῦ ἐξήγησις εἰς τὰ χαλδαϊκὰ λόγια*), *Patrologia Graeca*, vol. 122, col. 1129 (= Pselli *Opuscula*, p. 130): Αἴθριος ὀρνίθων ταρσός, πλατύς, οὔ ποτ' ἀληθής. Τουτέστιν, ἡ διὰ τῶν πετομένων ὀρνίθων ἐν τῷ ἀέρι τέχνη, ἣν δὴ καὶ οἰωνιστικὴν ὀνομάζουσιν, οὐκ ἔστιν ἀληθής, περιεργαζομένη πτήσεις αὐτῶν, καὶ κλαγγάς, καὶ καθέδρας.

19 The morphology of the liver of the sacrifice depends upon planetary aspects: Hephaistion, 3.6, p. 253, line 3–p. 255, line 17. Cf. Pselli *Opuscula*, p. 153. Psellos also wrote a treatise on omoplatoscopy (*Περὶ ὠμοπλατοσκοπίας καὶ οἰωνοσκοπίας*) edited by Herscher.

20 S. Gregory of Nyssa, *De Pythonissa, Patrologia Graeca*, vol. 45, col. 109: τούτου χάριν, ὡς ἂν μὴ πρὸς τὸν θεὸν οἱ ἄνθρωποι βλέποιεν, πολλοὺς τρόπους τῆς τοῦ μέλλοντος γνώσεως ἡ ἀπατηλὴ τῶν δαιμόνων ἐτεχνάσατο φύσις, οἰωνοσκοπίας, συμβολομαντείας, χρηστήρια, ἡπατοσκοπίας, νεκυΐας, ἐνθουσιασμούς, κατακωχάς, ἐμπνεύσεις, καὶ ἄλλα τοιαῦτα πολλά (see also Fögen, "Balsamon on Magic").

### 1.2 *Magic*

Magical practices date from the most remote past. Medeia, for example with her poisons, spells, and other magical rituals plays an essential part in the tale of Argonautica; aided by magic and her poisons, spells, and other rituals she helped Jason steal the golden fleece and then escape with her and his companions all with her father in pursuit. Plato argues against magic, comparing it with poisoning. He also distinguishes between the use of poisonous substances and the employment of spells that rely on psychological factors based on rituals, on "enchantment and charms and so-called binding spells," in order to persuade or to frighten. According to Plotinus (*c.* 204/5–270), magical spells function through sympathy and a sorcerer is someone who has learned to understand and to use the sympathetic powers inherent in the cosmos, turning them against other human beings. The one person that magic could not touch was the absolutely contemplative person, the ideal and perfect philosopher.[21] Magicians reinforced their influence over people by introducing many words from oriental languages into their spells and claiming that spells are efficient if and only if they are pronounced in their proper language.[22] But gradually the invocations began to be addressed to Christ, the Virgin, and other Saints. In this case, it was the good or evil intention of its user that characterizes a spell as religious or magical. We might consider the exorcisms written by the Fathers of the Church (for example, Saint Basil, Gregory the Theologian, and others) as religious spells through which the evil spirit is driven out of a person and sent far away into to desert lands or to the sea. On the other hand, Psellos says that old women sent demons to "the abyss and subterranean places and to material things."[23]

The interest of some high state or ecclesiastic officers in magic often derived from their thirst for personal power and political influence, especially

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21 Plato, *Leges* (*Laws*) 11.932e–933e. Plotinus, *Enneades* 4. 4. 40: Τὰς δὲ γοητείας πῶς; Ἢ τῇ συμπαθείᾳ, καὶ τῷ πεφυκέναι συμφωνίαν εἶναι ὁμοίων καὶ ἐναντίωσιν ἀνομοίων … καὶ ἡ ἀληθινὴ μαγεία ἡ ἐν τῷ παντὶ φιλία καὶ τὸ νεῖκος αὖ. Καὶ ὁ γόης ὁ πρῶτος καὶ φαρμακεὺς οὗτός ἐστιν, ὃν κατανοήσαντες ἄνθρωποι ἐπ' ἀλλήλοις χρῶνται αὐτοῦ τοῖς φαρμάκοις καὶ γοητεύμασι. Graf, "Theories of magic," pp. 97–99, 101–2. Otto, "Historicizing Magic," pp. 324–25.

22 Origenes' *Contra Celsum*, *Patrologia Graeca*, vol. 11, col. 708: Ἔτι δ' εἰς τὸν περὶ ὀνομάτων τόπον λεκτέον, ὅτι οἱ περὶ τὴν χρῆσιν τῶν ἐπῳδῶν δεινοὶ ἱστοροῦσιν, ὅτι, τὴν αὐτὴν ἐπῳδὴν εἰπόντα μὲν τῇ οἰκείᾳ διαλέκτῳ, ἔστιν ἐνεργῆσαι ὅπερ ἐπαγγέλλεται ἡ ἐπῳδή· μεταβαλόντα δὲ εἰς ἄλλην οἱανδηποτοῦν φωνήν, ἔστιν ἰδεῖν ἄτονον καὶ οὐδὲν δυναμένην.

23 *Patrologia Graeca*, vol. 31, col. 1681 (S. Basil, *Εὐχαὶ ἤτοι ἐξορκισμοὶ πρὸς τοὺς πάσχοντας ὑπὸ δαιμόνων, καὶ ἑκάστην ἀσθένειαν*); vol. 37, col. 1400 (S. Gregory, *Ἀποτροπὴ τοῦ πονηροῦ, καὶ τοῦ Χριστοῦ ἐπίκλησις*); vol. 115, col. 1240 (*Vita S. Abercii*); vol. 122, col. 869 (Pselli *Περὶ ἐνεργείας δαιμόνων*).

influence over the emperor. This was the case with the iconoclast Patriarch John VII Grammatikos (837–43), cousin of Leo the Philosopher (or Mathematician). Even before John's election as Patriarch, Theodore Stoudites (759–826) had compared him with Jambres, the Pharaoh's magician in the Bible. Patriarch Methodios I (843–47) and George Monachos (842–67) characterized him as "a magician and a diviner" (μαγόμαντις), "a dish-diviner," and "a master of diviners and demons." But in spite of his reputation, emperor Theophilos promised John the patriarchate because of his predictions "by dish-divinations and enchantments," including Basil I's (867–86) later succession to the throne. Moreover, the Patriarch John had in his possession an underground apartment built under his orders in a suburb of the European area of Constantinople in the luxurious villa of his brother, the patrician Arsaber. "In his evil laboratory, he kept out of sight pretty nuns for his pleasure as well as to be helped by them in his divinatory practices which included hepatoscopy, dish-divination, sorcery, and necromancy. Thus, John collaborating with demons had much success in his predictions regarding Theophilos and some of his trusty persons."[24]

In the course of describing the reign of Constantine IX Monomachos (1042–55) in his *Chronography*, Psellos recorded an example of iconomancy practiced by the Empress Zoe Porphyrogennete (1042) whom he praised for her piety and devotion to God. Zoe worshiped an icon of Jesus that she made and embellished; it was said that this icon looked so lifelike that it responded to requests (and thus called "Antiphonetes") and revealed future events by changes in its complexion. Zoe consulted the icon and "if she saw the face turn pale, she went away in dismay, but if it took on a high colour, she immediately reported this to the emperor and forecast to him what was going to happen."[25] Apart

24 Theophanes continuatus, book 4, §7, ed. Bekker, col. 155: καὶ τοῦ Θεοφίλου διδάσκαλος ἐγκαθίστατο. καὶ οὗτος ἐπεὶ τὰς τῆς βασιλείας ἔσχεν ἡνίας, σύγκελλον μὲν πρότερον τοῦτον τιμᾷ, εἶθ' ὕστερον καὶ πατριάρχην καθίστησι Κωνσταντινουπόλεως, προγνώσεις τινὰς διὰ λεκανομαντείας καὶ γοητείας αὐτῷ ἀπαγγέλλοντα. §8, col. 156: ἐκεῖνο γοῦν αὐτοῦ πονηρὸν ἐργαστήριον. ἐκεῖσε δὴ τούτῳ τινὲς νῦν μὲν ἐταμιεύοντο θαλαμηπολούμεναι, μονάζουσαί τε καὶ ἄλλως τὸ κάλλος γυναῖκες μὴ διαφθείρουσαι, αἷς συνεφθείρετο· νῦν δὲ μαντεῖαι δι' ἡπατοσκοπίας καὶ λεκανομαντείας καὶ γοητείας καὶ νεκυομαντείας ἐνηργοῦντο, ταύταις προσχρωμένου κοινωνοῖς τε καὶ βοηθοῖς. ὅθεν πολλάκις καί τινα προλέγειν τούτῳ συνέβαινε τῇ τῶν δαιμόνων συνεργείᾳ ἀληθῆ, οὐ τῷ Θεοφίλῳ μόνῳ ἀλλὰ καὶ ἑτέροις τοῖς τούτου ὁμόφροσιν. Magdalino, *L'Orthodoxie*, pp. 58–60.

25 Psellus, *Chronographia*, ed. Renauld, VI, ch. 65: ἓν τοῦτο θαυμάζων διατελῶ, ὅτι δὴ φιλοθεΐᾳ πάσας μὲν γυναῖκας, πᾶσαν δὲ φύσιν ὑπερεβάλλετο ἄρρενα. ch. 66: καὶ ἢν μὲν ὠχριακότα ἴδοι, ἀπῄει στυγνάζουσα, εἰ δὲ πυρράζοντα καὶ φανοτάτῃ αἴγλῃ καταλαμπόμενον, διήγγελλέ τε αὐτίκα τῷ βασιλεῖ τὸ πρᾶγμα καὶ προκατήγγειλε τὸ ἐσόμενον. Duffy, "Reactions of Two Byzantine Intellectuals," pp. 88–89.

from the imperial icon of Jesus "Antiphonetes," there was also the icon of the Virgin Mary of Blachernai consulted by the people of Constantinople. As Psellos says, they asked the icon specific questions related to their everyday affairs and checked Virgin's garments: if they moved, the answer was affirmative, if they did not, the response was negative.[26]

Another magical practice involved the making and use of amulets as healing and apotropaic objects. They were created either from silk cloth that contained a piece of parchment on which magical words were written (or phrases or letters or curious symbols), or of a lamella with inscribed magical spells or exorcisms prepared with the right incantations and ritual actions.[27] As amulets, the Byzantines also used magical stones and plants, as well as coins of Alexander the Great.[28] A gold lamella for a headache dated from the early 2nd century suggests that Christian invocations were introduced quite early.[29]

In the 6th century, the well-known physician Alexander of Tralles consented to the use of amulets and charms for therapeutic purposes. Like the best doctor he was always ready to use any means to heal his patients, suggesting that it would be immoral to neglect anything that could contribute to that healing. After a description of the making of a charm-ring accompanied with prayers and magical signs, he insisted that this information be divulged only to those who were virtuous and knew how to keep a secret.[30] Even in the middle

26 Ierodiakonou, "The Greek Concept of Sympatheia," p. 109. Psellus, *Λόγος ἐπὶ τὸ ἐν Βλαχέρναις γεγονότι θαύματι*, *Orat. Hagiogr.*, ed. Fisher, orat. 4, lines 112–31: Εἰκών τις αὐτῇ ἐν δεξιᾷ τοῦ νεὼ τοῖς πρὸς ἀνατολὰς εἰσιοῦσιν ἐκκρέματαί τε ἅμα καὶ ἐνήρμοσται ἀκριβῶς … καταπέτασμα δὲ αὐτῆς ἐξ ὑφαντικῆς τέχνης ᾐώρηται … ἐξίασι δὲ τηνικαῦτα τοῦ νεὼ ξύμπαντες … τελεσθέντων δὲ ὁπόσα τοῖς ἱεροτελεσταῖς νομίζεται, νόμος εὐθὺς ἀνεῴγνυσθαι τὰ ἀνάκτορα. καὶ τὰ μὲν ἀνέῳκται, καὶ εἴσοδος τοῖς ἐφεστηκόσι πρὸ τοῦ ναοῦ δέδοται, καὶ οἱ μὲν εἰσίασι φόβῳ καὶ χαρᾷ συμμιγεῖς, ὁ δὲ περὶ τὴν εἰκόνα πέπλος ἀθρόον μετεωρίζεται ὥσπερ τινὸς αὐτὸν ὑποκινήσαντος πνεύματος, καὶ ἔστι τὸ πρᾶγμα τοῖς μὲν μὴ ἰδοῦσιν ἄπιστον, τοῖς δὲ ἰδοῦσι παράδοξον καὶ τοῦ θείου πνεύματος ἄντικρυς κάθοδος … ἀλλὰ τὴν θεομήτορα ποιοῦνται διαιρέτιν τῆς ὑποθέσεως … τῇ κρίσει τοῦ περὶ τὴν εἰκόνα θαύματος τὸ πᾶν ἀναθέμενοι … στῆναι ἅμα ἡμέρᾳ κατέναντι τῇ τῆς θεοτόκου εἰκόνι … εἶτ' ἐπικαλέσασθαι τὴν ἐν τῇ εἰκόνι παρθένον καὶ θρηνῶδες ἀναβοήσασθαι δικάσαι αὐτοῖς τὴν δίκην καὶ τῷ πέπλῳ τεμεῖν.

27 Greenfield, "Palaeologan Magic," pp. 134–35.

28 Chrysostomi *Πρὸς τοὺς μέλλοντας φωτίζεσθαι κατήχησις δευτέρα*, *Patrologia Graeca*, vol. 49, col. 240: Τί ἄν τις εἴποι περὶ τῶν ἐπῳδαῖς καὶ περιάπτοις κεχρημένων, καὶ νομίσματα χαλκᾶ Ἀλεξάνδρου τοῦ Μακεδόνος ταῖς κεφαλαῖς καὶ τοῖς ποσὶ περιδεσμούντων;

29 Kotansky, "An early Christian gold lamella for headache," p. 37.

30 Alexander, *Therapeutica*, ed. Puschmann, vol. 2, p. 375: οἶδα μὲν οὖν, ὅτι ταῖς εἰρημέναις μεθόδοις χρώμενός τις οὐ μὴ δεηθῇ τινος ἄλλης ἐπικουρίας. ἀλλ' ἐπειδὴ τῶν περιοδευομένων πολλοὶ … διὰ περιάπτων φυσικῶν ἀναγκάζουσιν ἡμᾶς ἀποπαύειν αὐτῶν τὴν ὀδύνην, ἐσπούδασα καὶ περὶ τούτων ἐκθέσθαι ὑμῖν, ὧν τε αὐτὸς ἔσχον πεῖραν καὶ ὅσα παρὰ φίλων ἀληθινῶν ἔγνων

Byzantine period, the use of ancient apotropaic motifs continued. The evidence for this can be found in a lead amulet from Pythagoreion (Samos) with an eight-pointed star on its obverse face and the head of Medusa with seven rays ending in snakes or animal heads radiating from it on its reverse face.[31]

Finally, the prevalent belief in the "evil eye" was based on the assumption that a person's eyes both emit and receive an efflux from another person's eyes. Sophronios, Patriarch of Jerusalem (634–38), asked: "if men's evil eyes melt hard diamond, how could the human body not suffer by those who have evil eyes?" The evil eye can harm equally human beings, animals, and various objects. The effects of the evil eye could be annulled by unique spells and practices.[32] John Chrysostom condemned the practice of anointing a child's forehead with mud to protect it from the evil eye. Instead, he recommended that from its first years the infant be taught to make the sign of cross on its forehead and if the child was not able to do it alone, someone else should impress the shape of the cross on the child's forehead.[33] Among the dangers threatening a newborn's life up to the age of one year was a female demonic character called Gylou (Γυλλού, Γελλώ), identified with ancient demon Empousa. There were many exorcisms directed against her evil powers preserved in manuscripts dated from the 15th right up to the 20th(!) centuries, but the tradition goes back to the 4th–5th century. Psellos described the "Gelloudes" (pl.) as winged old women, which attests to the persuasive presence of this belief In Byzantine society.[34]

ὠφελεῖν δύνασθαι. p. 377 (making of a charm-ring), p. 475 reference to ancient physicians who wrote on sympathy and antipathy, especially to Galen's treatise on Homeric medicine. Duffy, "Reactions of Two Byzantine Intellectuals," p. 95.

31 Dafi, "A Byzantine Lead Amulet from Samos," pp. 241–47.

32 Sophronii, LXVIII. *De Joannia quae a maleficio torsiones patiebatur* (Σοφρωνίου, ξη′ *Περὶ Ἰωαννίας τῆς ἐκ περιεργείας στροφουμένης*), *Patrologia Graeca*, vol. 87/3, cols. 3656–57: Εἰ γὰρ ἀδάμαντα τὸν στερέμνιον, τῶν λίθων ἐπαινουμένων τιμιώτερον, τὸν χαλκῷ καὶ σιδήρῳ λεγόμενον ἄθραυστον, ὀφθαλμοὶ βασκάνων ἐκτήκουσι, τί ἂν ἀνθρώπειον σῶμα μὴ πάθοιεν βασκάνοις εἰς ἔργον προκείμενον; οἵτινες ὅτε καὶ βολαῖς ὀμμάτων μὴ φθίνουσι τὸ φθονούμενον, ἄλλοις αὐτὸ φθείρειν ὀργάνοις σπουδάζουσιν … Οἱ δὲ Θεοῦ φιλανθρωπίαν μιμούμενοι, δεινῶς αὐτὴν ἀπολλυμένην ἠλέησαν τοῖς ὁράμασιν τοῦ πάθους αὐτῇ τὴν θεραπείαν ὀρέξαντες.

33 J. Chrysostomi *In epist. I ad Cor. Homil. XII, Patrologia Graeca*, vol. 61, col. 105: Τί ἄν τις εἴποι τὰ περίαπτα καὶ τοὺς κώδωνας τοὺς τῆς χειρὸς ἐξηρτημένους καὶ τὸν κόκκινον στήμονα, καὶ τὰ ἄλλα τὰ πολλῆς ἀνοίας γέμοντα, δέον μηδὲν ἕτερον τῷ παιδὶ περιτιθέναι, ἄλλ' ἢ τὴν ἀπὸ τοῦ σταυροῦ φυλακήν; Dickie, "The Fathers of the Church and the Evil Eye," pp. 31–32.

34 Pselli *Opuscula* (De Gillo), p. 164.

## 2 Astrology

Among all divinatory arts astrology was the most sophisticated in terms of its philosophical context and the refined astronomical techniques required for casting a horoscope. As an art astrology is strongly related to the application of the Stoic principle of sympathy among all parts of the world.[35] The celestial bodies have, therefore, an influence upon all things on earth and especially on man. A very subtle spirit composed mostly of fire and air permeates all things (stones, minerals, metals, waters, plants, animals, human beings) thus becoming their underlying principle.[36] According to the famous astronomer Claudius Ptolemy (2nd century), "a certain power emanating from the ethereal substance is dispersed through and permeates the whole region about the earth, which throughout is subject to change." But he also pointed out that every science that deals with a theory about the quality of matter is "conjectural, and not to be affirmed absolutely; due to various factors this is also true for knowledge attained by astronomical means."[37]

Throughout the Roman Empire astrology was considered the most accurate method of divination. Any emperor, therefore, felt bound to use it to be warned of future dangers either to the empire or to himself and to appease those with excited thoughts by withholding from them the stimulus of astrological predictions, while retaining for himself the counsel of his court astrologers. Since its founder, the emperor Hadrian, was both a firm believer in astrology and a practicing expert himself,[38] it seems very likely that astronomy, and presumably the theory of astrology, were both taught in the Roman state university, the Athenaeum, from its beginnings in 134 CE. On the other hand, from Caesar's death (44 BCE) to that of Marcus Aurelius (180 CE) at least eight expulsion decrees were issued against astrologers, all meant as temporary measures. For this reason, astrologers were allowed to stay in Rome on condition that they did not practice their art. In 294 CE, Diocletian was the first to replace the traditional regional ban on astrology with an empire-wide prohibition of all divinatory activities considered dangerous by the government, his edict having the same temporary character as had previous regional edicts. Much later, for religious reasons, Christian emperors changed these edicts to permanent ones.[39]

35 Bouché-Leclercq, *L'astrologie grecque*, pp. 28–29, 31.

36 Chrysippus, *Fragmenta logica et physica*, ed. Arnim, p. 145, line 41–p. 146, line 2.

37 Ptolemy, *Apotelesmatica* (= *Tetrabiblos*) 1.2, ed. Waddell pp. 4–6, 14–18.

38 See also chapters 2 and 6 of this volume.

39 *Codex Theodosianus* 9.16, *Codex Justinianus* 9.18; Cramer, *Astrology in Roman Law*, pp. 232–33, 247–48, 281.

The significant number of horoscopes dating from the early Christian centuries is a mark of the considerable activity of astrologers' sustained activity during this period.[40] Westerink showed that an ancient commentary on Paul of Alexandria's astrological work (*c.* 378) comes from a series of lectures given in May-June 564 in Alexandria either by Olympiodoros or by one of his disciples who taught mathematics or astrology. Thus, he concludes that in the 6th century astrology was an essential part of the *Quadrivium* and, consequently, part of curriculum of philosophy.[41] It seems very likely then that Stephanos of Alexandria (late 6th–early 7th century) had the opportunity to study astrology there, hence his invitation to Constantinople by the emperor Herakleios (610–41) to cast the horoscope of the emperor.[42] An astrological treatise related to the Horoscope of Islam is also attributed to him,[43] but this authorship is disputed.[44]

Even later Christian emperors were interested in consulting astrologers both for their personal and state affairs. We know that in 792 a court astrologer of Constantine VI (780–97) named Pankratios, was condemned to death because of his erroneous prediction of the emperor's victory over the Bulgarians.[45] The activity of Leo the Philosopher (or Mathematician), said to be the most significant wise man of his time, occupies the period of the emperors Theophilos (829–42) and Michael III (842–67). His expertise in astrology derived from his possession of the astrological treatise of Paul of Alexandria,[46] and from some astrological treatises saved under his name. His reputation as an astrologer reached as far as the court of Abbassides.[47] Among Leo's many

40 Neugebauer/Van Hoesen, *Greek Horoscopes*.

41 Westerink, "Ein astrologisches Kolleg," pp. 6–21.

42 Theophanes Continuatus, ed. Bekker, col. 338, lines 10–12. Ostrogorsky, *Geschichte des byzantinischen Staates*, pp. 77–93.

43 Ed. Usener, *De Stephano Alexandrino*, pp. 247–322. Papathanassiou, *Stephanos von Alexandreia*, pp. 47–55; idem., "Στεφάνου Ἀλεξανδρέως Ἀποτελεσματικὴ Πραγματεία"; idem., "Stephanos of Alexandria: A Famous Byzantine Scholar."

44 Magdalino, *L'Orthodoxie*, pp. 34, 85–87; on Stephanos' personality and the cultural environment in Constantinople during the 7th and the 8th century, see *ibidem*, pp. 33–54.

45 Theophanes, *Chronographia*, ed. de Boor, pp. 467–68 θερμοπνοήσας δὲ ὁ βασιλεὺς καὶ ὑπὸ ψευδοπροφητῶν πεισθείς, ὡς αὐτοῦ ἔσται ἡ νίκη, ἀσκόπως καὶ ἀτάκτως συνέβαλε πόλεμον καὶ ἡττᾶται σφοδρῶς. ἐπανέρχεται δὲ φυγὰς ἐν τῇ πόλει πολλοὺς ἀποβαλὼν … καὶ Παγκράτιον τὸν ψευδοπροφήτην καὶ ἀστρονόμον, ὅστις καὶ νικᾷν αὐτὸν προεφήτευσεν.

46 Hunger, vol. 2, p. 239: Nun befand sich nicht zufällig unter den Büchern Leons auch ein Codex der Astrologie des Paulos von Alexandreia, auf den der Philosoph die beiden Hexameter schrieb (A.P. IX 201) "Paulos, der ruhmvolle Mann, der Kenner der Sterne, enthüllte mir das hehre Geheimnis der Weissagekünste des Phoibos."

47 Magdalino, *L'Orthodoxie*, p. 62.

students who continued the practice of scientific philosophy, particularly astrology, was Leo Choerosphaktes (born *c.* 845–850) who exerted an influence over emperor Leo VI the Wise (886–912); Leo asked an astrologer to cast the horoscope of his son, the future emperor Constantine VII Porphyrogennetos (913–59).[48] Co-emperor with Constantine VII, Romanos I Lekapenos (920–44) also had his private court astrologer. Some years later, emperor Nikephoros II Phokas (963–69) was so much in favour with court astrologers (as we can deduce from the report of Otto I's delegate, Liutprand) that they were free to talk with foreign ambassadors. The official delegate was astonished by an astrologer reporting to him facts regarding him and his lord with extraordinary accuracy.[49] The anonymous translation from Arabic to Greek of Albumasar's (787–886) famous astrological work *De revolutionibus nativitatum* also dates back to that century. Nine horoscopes dated between 972 and 1011[50] offer substantial evidence of the rise of astrology during the reign of Basil II Bulgaroktonos (976–1025), even if we ignore the number and the names of the court astrologers who were active from 972 to 1019.

The 11th-century scholar Michael Psellos (*c.* 1018–93) represents the culmination of philosophy and the occult sciences in Byzantium during these forty years. In his *Chronography* he refers twice to astrology, first regarding the decision of Michael V (1041–42) to expel Empress Zoe, and second regarding his tonsure at the appropriate time, namely a little before the death of Constantine IX Monomachos (1042–55) who referred to specific prophecies and auguries connected with his reign.[51] In the 12th century, Anna Komnena mentioned the names of four astrologers who were active during the reign of her father, Alexios I Komnenos (1081–1118) in her *Alexiade*. They are: Seth, Eleutherios, Katanankes, and Theodore. They may be the magister and philosopher Symeon Seth, native of Antiochia; Eleutherios Zebelenos who offered as an example his native horoscope together with the Athenian Katanankes, and Theodore

48 Pingree, "The horoscope of Constantine VII," pp. 217–19, 229–30.

49 Magdalino, *L'Orthodoxie*, p. 83.

50 These horoscopes were cast for the following dates: 12 September 972, 7 Mai 977, 11 October 983, 21 September 1002, 7 December 1003, 15 September 1006, 1 June 1007, 29 August 1011, and 13 October 1011. Magdalino, *L'Orthodoxie*, p. 91.

51 Psellus, *Chronographia*, ed. Renauld, ch. 5, § 18: … τοῖς δὲ ἐδόκει εἰς μαθηματικὴν πρόγνωσιν ἀναθεῖναι τὸ βούλευμα καὶ γνῶναι εἰ εὔθετος πρὸς τὴν κατάπραξιν ὁ καιρός, καὶ μή τι σχῆμα τῶν οὐρανίων ἐμποδίζοι τῷ ἐγχειρήματι· ὁ δὲ τούτων ἁπάντων σεμνὸς ἀκροατὴς προκαθήμενος … χαίρειν εἰπὼν τὸ ἐσόμενον διὰ τῶν ἀστρονομούντων ἐμάνθανεν. Also §§ 19–20. ch. 6, § 96: καὶ αὐτὸς δὲ ὁ αὐτοκράτωρ, ὁπότε προφητείαις τισὶ καὶ οἰωνίσμασι τὴν ἑαυτοῦ ἡγεμονίαν ἐσεμνολόγει, ὀπτασιῶν τέ τινων καὶ ὀνειράτων παραδόξων ἐμέμνητο, τὰ μὲν ὡς αὐτὸς ἰδών, τὰ δ' ὡς ἄλλων μαντευομένων ἀκροασάμενος, καὶ τὸ περὶ τούτου μέρος παραδοξολογῶν ἦν.

Alexandrinos, a specialist in prognostications regarding horse races in the Hippodrome. Although we do not know the names of astrologers who consulted Michael VII Doukas in 1078 (as reported by Michael Attaleiates), it is very likely that they were the same Seth and Zebelenos.[52]

Astrology flourished especially during the reign of Manuel I Komnenos (1143–80) who openly defended astrology, but kept a secret watch on the astrologers of his time. The chronographer Niketas Choniates occasionally mentions some of their names. He also reports that Emperor Manuel I condemned Skleros Seth (possibly the son or grandson of Symeon Seth) and Michael Sikidites (to be identified with Michael Glykas) to blindness because they pretended to practice astrology while they practiced magic.[53] Manuel defended astrology in a letter addressed to the monk Michael Glykas, while the later refuted it in his answer.[54] Among a number of arguments, Manuel I emphasized how patriarchs and emperors alike approved of astrology. For instance, the Archbishop of Thessaloniki (i.e., Leo the Philosopher or Mathematician) practiced astrology, while many centuries earlier emperor Constantine I the Great consulted the famous astrologer Vettius Valens for the most favourable date for the inauguration of Constantinople so that it would be able to resist enemy attack.[55] As shown by Neugebauer, this so-called *Horoscope of Constantinople* should be attributed instead the 10th-century astrologer Demophilos, who used Ptolemy's *Almagest* or the *Handy Tables* in *c.* 990 to cast the horoscope and the work of Vettius Valens interpret its meaning.[56] It seems very likely that Manuel also encouraged John Kamateros to write his *Introduction to astrology*, where he summarizes the works of Ptolemy, Hephaistion, and Maximos of Byzantium, the tutor of emperor Julian (360–63). In the same period, Constantine Manasses wrote a verse *Introduction to astrology* dedicated to sebastokratorissa Irene, the emperor's sister in law.[57] Finally, the chronicler Choniates also mentions Constantine Stethatos, "the most considerable among the astrologers of this time," who lost his life as he participated in the revolt of Alexios Branas (1187) against Isaac II Angelos (1185–95).

It is noteworthy that modifications to the relevant legislation were always possible according to variations in circumstances. For example, a comparative

52 Magdalino, *L'Orthodoxie*, p. 96–102.

53 Magdalino, *L'Orthodoxie*, p. 109–110.

54 George, "Manuel I Komnenos and Michael Glykas," pp. 1–48.

55 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 5.1, pp. 108–25, here p. 116, lines 28–31, p. 118, line 14–p. 119, line 22.

56 Neugebauer, "The Horoscope of Constantinople," p. 306.

57 This poem published under the name of Theodore Prodromos should be attributed to Constantine Manasses: Hunger, vol. 2, p. 243. Magdalino, *L'Orthodoxie*, p. 112.

study of the body of laws in the 8th and 9th–10th centuries shows that under the Macedonian dynasty legislators were more aggressively hostile to magic than under the Isaurians, whose own milder legislation brought about of the corresponding laws in the Codex Justinianus.[58] Most astrologers of the 11th and the 12th centuries were laics in contrast to earlier periods. This was probably due to the stricter application of canon No. 36 of the Laodicea council that forbade magicians, sorcerers, mathematicians, and astrologers amongst the priesthood. The 12th-century canon legislators did not modify the prohibitions against astrology, but instead defined them in a stricter sense. John Zonaras commenting on the same canon decreed that the study of the *Quadrivium* of mathematics, including astronomy, was permitted to those who observed the movement of the celestial spheres and bodies. In contrast, the curious examination of the zodiacal signs and their use for personal fortune telling were all forbidden. Theodore Balsamon, another canon legislator of the same century, defined mathematicians as persons who divine the future through the stars, aided by the demons in which they believe.[59] Manuel I distinguished clearly between astrologers and those who invoked stars and talked with them, however he explained that due to ignorance of this distinction, astrology was misunderstood and astrologers were wrongly called magicians.[60]

Prominent 14th-century scholars rejected astrology, yet interpreted eclipses as omens of the death of an emperor or an empress. George Akropolites, a renowned scholar at the court of Nicaea, who knew the scientific explanation of the solar eclipse of 3 June 1239, still drew the following conclusion: "This empress [sc. Eirene], as I said, died, and I think that the eclipse of the Sun announced her death; and a comet had appeared in the north six months previously."[61] Later George Pachymeres, although he rejected individual astrological predictions connected with the natal horoscope (θέμα) and criticized astrologers, provided plenty of information about astrological theories; moreover, he saw the solar eclipse of 16 August 1258 as announcing the death of Theodore Lascaris. A note in the Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 191, fol. 319v, dated to the end of the 13th century, records an earthquake that

58 Troianos, "Zauberei und Giftmischerei," pp. 37–51, 184–88.

59 Magdalino, *L'Orthodoxie*, p. 128. Bouché-Leclerqc (*L'astrologie grecque*, p. 533, note 1) based on Tertullian and Pliny considers iatromathematica as magic combined with astrology.

60 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 5.1, p. 112, lines 6–10.

61 George Acropolites, *Opera*, ed. Heisenberg/Wirth, p. 64: Θνήσκει μέν, ὡς ἔφην, ἡ βασιλὶς αὕτη, οἶμαι δὲ καὶ τὴν τοῦ ἡλίου ἔκλειψιν τὸν αὐτῆς προσημᾶναι θάνατον· καὶ κομήτης δὲ πρὸ μηνῶν ἓξ περὶ τὸ μέρος ἀνεφάνη τοῦ βορρᾶ. Tihon, "Astrological Promenade," p. 268.

occurred in Constantinople fifteen days after the lunar eclipse of 18 May 1296. According to the *Roman History* of Nikephoros Gregoras, the death of Andronikos II Palaiologos on 12 February 1332 was announced by the solar eclipse of 30 November 1331; other eclipses in 1337, 1341 and 1342 foretold further misfortunes.[62]

An anonymous dialogue *Hermippos* or *On astrology* dating from the 14th century is attributed to various scholars.[63] Finally, John Abramios, astronomer-astrologer of emperor Andonikos IV Palaiologos (1376–79) had an astrological school that produced many astronomical and astrological codices.[64]

### 2.1 *Iatromathematica*[65]

According to Claudius Ptolemy, the "Egyptians have entirely united medicine with astronomical predictions through what they call their iatromathematical systems."[66] Using iatromathematica (medical astrology) physicians could better understand the temperament of an individual man and analyse his bodily constitution and psychic faculties,[67] his inclination to chronic and acute diseases, the possibilities of curable or incurable cases, and finally the periods which posed significant danger to his health. They could also conjecture the evolution of a disease, choose a favourable time for an operation, or initiate a cure. A poem saved in a Greek manuscript dated to the 16th–17th centuries praises physicians who were also astrologers, and like Krinas (1st century in Rome) know the proper time to give medicines to their patients.[68]

Iatromathematica inherited from Greek philosophy and medicine the four primary elements (fire, air, water, earth) and their correspondence with the four humours of the human body (fire-yellow bile, air-blood, water-phlegm,

62 Nicephorus Gregoras, *Historia Romana*, IX, 14,1 (ed. Bekker/Schopen, vol. 1, col. 460): Καιρὸς δὲ ἤδη καὶ περὶ τῆς τοῦ γηραιοῦ βασιλέως διεξελθεῖν τελευτῆς, ἣν θεοσημεῖαι πολλαὶ προεμήνυσαν· αἵ ἦσαν τοιαῖδε. ἐπισκότησις πρῶτον ἡλιακή, τοσαύτας ἡμέρας προειληφυῖα τὴν αὐτοῦ τελευτήν, ὅσα καὶ αὐτὸς ἦν ἔτη τὰ πάντα βεβιωκώς. Ταύτην τὴν ἡλιακὴν ἐπισκότησιν ἔκλειψις διεδέξατο σεληνιακή … κατ' αὐτὴν μέν γε τὴν τοῦ φεβρουαρίου δωδεκάτην ἡμέραν. Tihon, "Astrological Promenade," pp. 268, 272, 275, 286–87.

63 Jürß, "Johannes Katrarios," p. 282. Magdalino, *L'Orthodoxie*, pp. 154–57.

64 Pingree, "The astrological school of John Abramius," pp. 191–205.

65 Papathanassiou, "Iatromathematica," pp. 357–76. Piperakis, *Αστρολογία και Ιατρική.*

66 Ptolemy, *Tetrabiblos* 1.3, pp. 30–32.

67 Whether somebody is endowed by nature with the virtue of divination or not depends upon his natal horoscope: Ptolemy, *Tetrabiblos* 4.4, p. 390.

68 Sankt-Peterburg, Rossijkaja Nacionalnaja Biblioteka, Petropolit. gr. 180, fol. 184 (see *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 12, Cod. 8).

earth-black bile) as well as the two pairs of opposite qualities (hot-cold, dry-humid) relating them one to the other.[69] The twelve zodiacal signs form four triplicities corresponding to the four elements, and the seven planets (sun and moon included) are related to the four qualities according to the powers they manifest; zodiacal signs and planets rule plants and minerals used in certain remedies. In the works attributed to Hermes Trismegistos[70] a patient's temperament and the symptoms of his disease indicate which treatment was required according to the principle of opposite qualities; thus remedies are classified into various categories according to their qualities and combinations.[71] Two qualities, warm and humid, are considered fertile and active, while the other two, cold and dry, are considered destructive and passive. According to the qualities assigned to the planets the latter are distinguished into beneficent and maleficent planets.

The rising degree of the zodiac at the time of birth is called Horoscopos (Ascendant), and its observation should be made using horoscopic astrolabes, the only instruments accurate enough to give the exact minute of the hour to knowledgeable observers. In a natal horoscope, the sign of the Horoscopos together with those of the sun's and the moon's positions play a significant part in the formation of a man's physical constitution and his personality as a whole. According to Hermes Trismegistos both at conception and birth, rays emanating from the seven planets are mingled on every part of a person's body according to their positions in the twelve signs. On the basis of an old rule of Petosiris (2nd half of the 4th century BCE), Hephaistion, and other astrologers gave special instructions for the calculation of the exact time of conception from the time of birth.[72]

According to this model, the microcosm-man is an image of the macrocosm-zodiac. Thus, the major parts and organs of the human body are assigned under the tutelage of the twelve signs and their rulers, known as "melothesia"

69 Papathanassiou, "Stephanus of Alexandria: Pharmaceutical notions," pp. 125–33.

70 Treatises contained in *Corpus Hermeticum* may date from the 2nd century BC to the 3rd century CE.

71 Ideler, vol. 1, pp. 387–96, *Ἰατρομαθηματικὰ Ἑρμοῦ τοῦ Τρισμεγίστου πρὸς Ἄμμωνα Αἰγύπτιον*; pp. 430–40, *Ἑρμοῦ τοῦ Τρισμεγίστου περὶ κατακλίσεως νοσούντων προγνωστικά, ἐκ τῆς μαθηματικῆς ἐπιστήμης πρὸς Ἄμμωνα Αἰγύπτιον*; here p. 389, line 36–p. 390, line 23; p. 432, line 36–p. 433, line 19.

72 Hephaistion, 2.1, pp. 81–88, here p. 82, lines 10–14; p. 83, lines 5–12; Hephaistion cites his own horoscope (p. 87, lines 3–24), see Neugebauer/Van Hoesen, *Greek Horoscopes*, p. 131, No. L380. Heliodorus (astrol.), *Commentarium in Paulum Alexandrinum*, ed. Boer, chs. 36–37, pp. 124–26. Also *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 2, p. 116, line 19–p. 117, line 10; p. 186, line 15–p. 187, line 3.

(μελοθεσία). Moreover, the planets are lords of special parts and organs of the human body.[73] According to their positions in the signs, in the two angles of the horizon (Horoscopos-Ascendant and its opposite degree, the Descendant) and in the sign preceding the Descendant, as well as their aspects to one another and to other planets, the maleficent planets can cause either injuries or diseases in those parts of the body, which are related to these signs.[74] Long ago physicians understood the moon's influence on epileptic patients.[75] Thus Aretaios of Cappadocia (fl. 2nd century) in his *De causis et signis diuturnorum morborum* (*On the causes of chronic diseases*) says that "the disease (epilepsy) reaches the moon," hence they named it "sacred."[76] It was advised that a physician-astrologer (iatromathematician) should cast a horoscope for the exact time at which the patient took to bed, or his disease was made known, or the physician came on the scene. Then the physician should check the moon's position and aspects, since this would reveal the kind and the cause of the disease.[77]

In his work *De diebus decretoriis* (*On critical days*), Galen, based on Hippocrates' related work and on astronomical data regarding the exact time of the revolutions of the sun and the moon in the zodiac, explains the influence of these celestial bodies upon chronic and acute diseases.[78] In Ps.-Galen's *De decubitu ex mathematica scientia*,[79] the cause and the evolution of disease depends upon the moon's position in the signs, its phases and age, and its strong aspects to the maleficent and beneficent planets at the time of the manifestation of the disease. Physicians knew how the moon's phases influenced the evolution of a disease,[80] while Hephaistion of Thebes (born 380) explained how critical days were related to the moon's position from the time the disease started. Important, too, were the moon's phases in various signs and her aspects to the maleficent planets.[81] According to Hephaistion special care

73 Ideler, vol. 1, p. 387, lines 6–11; p. 430, lines 6–11. Ptolemy, *Tetrabiblos* 3.12, pp. 318–19.

74 Ptolemy, *Tetrabiblos* 3.12, pp. 316–32. Hephaistion, 2.13, pp. 140–45.

75 Ptolemy, *Tetrabiblos* 3.14, pp. 362–72. Hephaistion, 2.16, pp. 150–53.

76 Aretaeus, *De causis et signis diuturnorum morborum libri duo*, 1.4.2, ed. Hude.

77 Ideler, vol. 1, p. 388, line 17–p. 389, line 6; p. 431, line 15–p. 432, line 6. *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 2, p. 157, lines 11–25.

78 Γαληνοῦ *Περὶ κρισίμων ἡμερῶν*, ed. Kühn, vol. 9, pp. 761–941; here p. 912. Cramer, pp. 188–90. Toomer, "Galen on the Astronomers und Astrologers," pp. 193–206.

79 Γαληνοῦ *Περὶ κατακλίσεως προγνωστικὰ ἐκ τῆς μαθηματικῆς ἐπιστήμης*, ed. Kühn, vol. 19, pp. 529–73. Weinstock, "The author of Ps.-Galen's Prognostica de decubitu," pp. 41–43.

80 Wellmann, *Die Fragmente der sikelischen Ärzte*, p. 167, Fr. 99: Galen, ed. Kühn, vol. 19, p. 530. Wellmann, "Zu Diokles," pp. 464–68.

81 Hephaistion, 3.5, p. 246, lines 4–15; 3.31, pp. 290–91.

should be taken for surgical operations regarding the phase and the place of the moon in the zodiac, and its aspects to beneficent and maleficent planets.[82] Aëtios of Amida (born *c.* 500), the well-known physician of the time of the emperor Justinian I (527–65), also refers to favourable and unfavourable critical days.[83] The same is true for the 11th-century Michael Psellos in his *Carmen De re medica*.[84] Moreover, numerous Byzantine manuscripts contain anonymous treatises with lists stating the expected evolution of a patient's disease according to its manifestation in each day of a synodic month.[85]

In the 12th century, Manuel I Komnenos' defence of astrology criticized the ignorant man who does not understand the importance of old astrological rules in medicine. He offers the following example: "Do not touch with iron (i.e., do not operate) that part of the body which is related to the sign in which the moon is," and "Do not give a purgative when the moon is in conjunction with Jupiter."[86] In the 14th century, in his *Ἐξήγησις εἰς τὴν σύνταξιν τῶν Περσῶν* (*Commentary on the Persian astronomical system*) (1347), the famous scholar George Chrysokokkes insisted on the links between astronomy and medicine. For this reason, he added some material useful to astrologers at the end of his work.[87]

### 2.2 *Plants Assigned to Signs and Planets; Magical Stones*

According to the Stoic principle of sympathy, zodiacal signs and planets are related to metals, stones, plants,[88] and animals.[89] Furthermore these are also related to parts and organs of the human body. Consequently, a physician should be able to cure his patients by using those plants (or other substances) that are sympathetically related to the afflicted parts or organs. Ancient and medieval works that refer to correspondence among signs, planets, and plants,

82 Hephaistion, 3.32, pp. 292–93.

83 Aëtii Amideni *Libri medicales* (*Corpus Medicorum Graecorum* 8), 2 vols., ed. Olivieri, Leipzig, 1 (1935), 2 (1950), vol. 2, book 5, ch. 25 *Ὅσαι ἀγαθαὶ κρίσιμοι ἡμέραι καὶ ὅσαι φαῦλαι.*

84 Ideler, vol. 1, pp. 203–43, *Τοῦ σοφωτάτου Ψελλοῦ καὶ ὑπερτίμου πόνημα ἰατρικὸν ἄριστον δι' ἰάμβων*; here pp. 210–11, lines 254–82.

85 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 3, p. 39, line 25–p. 40, line 29.

86 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 5.1, p. 111, lines 7–28.

87 Tihon, "Astrological Promenade," p. 279.

88 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 8.3–4, p. 137, line 16–p. 138, line 2.

89 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 4, pp. 122–23.

and also contain recipes for curing various diseases, are preserved in Byzantine manuscripts dated to the 14th to the 16th centuries. Most important among these works are *Harpocration's letter addressed to Caesar Augustus*, and that of *Hermes Trismegistus to Asclepius*.[90] Their accurate medical terminology and detailed instructions for the preparation of remedies with the exact proportions of the ingredients are indicative of their origin in Alexandria's scientific environment.[91]

They advise that every plant be collected from its proper country, according to the combinations of the planets and the signs of the zodiac with the regions of the Oecumene.[92] For example, the power of the poisonous plant hemlock (Conium maculatum), assigned to the planet Mars and the sign of Scorpio, is intensified when used in Italy. Thus, hemlock being under the influence of the sign of Scorpio becomes very deadly poison there. In contrast, in the island of Crete (Greece) it is an edible and very nutritious plant because the planet Jupiter, assigned to Crete, changes the quality of hemlock.[93] Also, it is better that someone use plants collected from warm countries because in warm climates the pores of the plants are looser and "the pneuma of vital air penetrates into them and makes the plants mighty and more efficient." Moreover "the plants should be collected in that day of the week and in that hour of the day both ruled by the planet who rules that particular plant," so that the healing power of the plant increases. Consequently, the best time for the collection of plants is immediately after sunrise, as the first seasonal hour of a day of the week is also ruled by the ruler of the day. An additional condition is that the moon should fall in a sign governed by the same planet-ruler of the day.[94] Finally, the proper time to extract the juice of plants is when the sun is exalted in Aries and possesses its maximum power.[95]

The root-cutter who digs up the plant should recite a special prayer to the Demiurge "who created not only the things which are naturally united (or congenital) and in agreement, but also the things that are not sympathetically

90 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 8.3–4, pp. 132–53 (Harpocration), 153–65 (Hermes).

91 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 8.3–4, p. 135, lines 7–16, 22–24.

92 Ptolemy, *Tetrabiblos* 2.3, pp. 128–60.

93 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 8.3–4, p. 138, lines 3–13.

94 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 8.3–4, p. 163, line 15–p. 164, line 7; lines 20–21.

95 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 8.3–4, p. 139, lines 1–11.

related and discordant," and pray him "to mix and unite all these in a temperate compound." He should also put a grain of wheat or barley into the hole opened as he drew up the plant to restore the damage caused to the environment.[96] Some root-cutters had excellent knowledge of the healing qualities of the plants as they were also pharmacologists. Such is the case of Krateuas (*c.* 100 BCE), who served as Mithridates VI's court pharmacologist and his treatise entitled Ῥιζοτομικόν (Root-cutting) along with other detailed studies on the use of metals and of spices as remedies constitute an early materia medica and the primary source of Dioscorides' *Materia medica*.[97]

In his *Chronographia* (*Chronography*), Psellos cites some exciting details about empress Zoe's (1042) way of living that reveal that she practiced plant alchemy to extract the essential oils from various plants. Her apartment was converted into a workshop where braziers blazed winter and summer. Here servants helped Zoe and her sister measure out the herbs, boil the mixture, and catch the stream of perfume as it flowed off.[98] This description suggests that Zoe practiced distillation by boiling plants in water and that she had at her disposal all the necessary instruments to achieve this: balance, heating source, a fractionating flask filled with plants and water, reduction head, some kind of condenser, and a receptacle for the distillate. Why did Zoe show this great interest in the extraction of essences? It is clear that it must have been related to her iconomancy and the offering of aromatic perfumes to the icon of Jesus "Antiphonetes." Psellos wishing to eliminate any suspicion of an impious magical use of perfumes by the empress, states clearly that "that woman, in her

96 *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 8.3–4, p. 164, lines 8–10; p. 164, line 22–p. 165, line 8.

97 Dioscorides, *De materia medica*, ed. Wellmann, Berlin 1914, book 1, prooim., lines 9–10. *Astrologica*, ed. Cumont et al., *Catalogus Codicum Astrologorum Graecorum*, vol. 7, p. 232 Γαληνοῦ *Περὶ κράσεως καὶ δυνάμεως τῶν ἁπλῶν φαρμάκων* 7 (vol. 11 Kühn, pp. 795, 797). *Der kleine Pauly*, vol. 3, p. 329, v. Krateuas. On Dioscorides, see chapter 9 of this volume.

98 Psellus, *Chronographia*, ed. Renauld, VI, ch. 64: περὶ τοῦτο δὲ μόνον ἐπόνει καὶ τὴν πᾶσαν πραγματείαν συνέτεινεν, τὰς τῶν ἀρωμάτων φύσεις μεταβάλλειν, καὶ μυρεψεῖν, τὰ δὲ πλάττειν τε καὶ τυποῦν, τὰ δ' ἄλλως ἐργάζεσθαι, καὶ ὁ ἀποτετμημένος αὐτῇ οἶκος εἰς εὐνὴν οὐδέν τι σεμνότερος ἦν τῶν ἐπὶ τῆς ἀγορᾶς ἐργαστηρίων, ἐφ' ὧν αἱ βάναυσοι τῶν τεχνῶν καὶ ἐμπύριοι τὴν ξυντέλειαν ἔχουσι· πυρὰ γοῦν πολλὰ πέριξ τοῦ δωματίου αὐτῆς ὑπανήπτετο, καὶ τῶν ἀμφιπόλων ἑκάστη ἡ μὲν τὰ μεγέθη τῶν ἀρωμάτων διῄρει, ἡ δὲ ταῦτα συνέπλαττεν, ἡ δ' ἄλλο τι τοιοῦτον εἰργάζετο.

worship of God, did not act in any Hellenic or magical way"[99] and explains that her purpose was to praise God by offering her perfumes:

> One matter above all claimed her attention and on this she expended all her enthusiasm—the offering of sacrifice to God. I am referring, not so much to the offering of praise or of thanksgiving or of penitence, but to the offering of perfumes (aromata) and of all those products which come into our land from India and Egypt.[100]

Cosmic sympathy also included stones. Among earlier works regarding their healing powers, the most important and extensive are those under Orpheus' name: *Ὀρφέως Λιθικά* (*Orphica Lithica*) in its 774 verses describes 29 magical stones, while *Ὀρφέως Λιθικὰ κηρύγματα* (*Orphica Lithica kerygmata*) describes 53 stones. There is also a short treatise *Περὶ λίθων* (*On stones*) under the names of Socrates and Dionysios and a very short nautical lapidary.[101] According to archbishop Epiphanios (end of the 4th century), the twelve precious stones of the archbishop's pectoral cross possessed special healing powers.[102] Much later Michael Psellos in his treatise *De lapidum virtutibus* (*On the powers of stones*) records, alphabetically, the healing powers of twenty four stones.[103] The high number of popular medical texts called *iatrosophia* (pl.) that have been preserved shows that Iatromathematica played an essential role amongst the Byzantines at all times.[104]

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99 Psellus, *Chronographia*, ed. Renauld, VI, ch. 67: ἐκείνη δὲ οὔτε ἑλληνικώτερον, οὔτ' ἄλλως περιεργότερον τὴν περὶ τὸ θεῖον ἐποίει τιμήν, ἀλλὰ τὸν τῆς ψυχῆς πόθον ἐπιδεικνυμένη καὶ καθοσιοῦσα Θεῷ τῶν παρ' ἡμῖν δοκούντων ἀγαθῶν τὰ τιμιώτερα καὶ σεμνότερα.

100 Psellus, *Chronographia*, ed. Renauld, VI, ch. 159: ἑνὸς δὲ μάλιστα εἴχετο καὶ περὶ τοῦτο σπουδὴν ἐτίθετο πᾶσαν, θυσίαν προσάγειν Θεῷ, οὐ φημι τοσοῦτον τὴν δι' αἰνέσεως λογικῆς τε προσαγωγῆς καὶ ἐξομολογήσεως, ἀλλὰ τὴν δι' ἀρωμάτων καὶ ὅσα τῆς Ἰνδῶν καὶ Αἰγυπτίων γῆς εἰς τὰ ἡμέτερα φοιτᾷ ὅρια. Duffy, "Reactions of Two Byzantine Intellectuals," pp. 89–90.

101 *Lithica kerygmata*, ed. Halleux/Schamp, pp. 166–77, 188–89. Also p. xxvi: "Sont cités comme auteurs de lapidaires: Nicias de Mallos, Archelaos, Aristobule, Agatharchide de Samos, Thrasylle de Mendès, Héraclite de Sicyone, Dercyllos, Dorotheos le Chaldéen." In a Latin lapidary published under the names Damigéron-Évax, according to twelve manuscripts dated in the 11th–14th century, the names of the 80 stones are a transliteration of their Greek names.

102 *Patrologia Graeca*, vol. 43, cols. 293–304.

103 Ideler, vol. 1, pp. 244–47: *Ψελλοῦ περὶ λίθων δυνάμεων*.

104 On *iatrosophia*, see chapter 10 of this volume.

## 3 Alchemy

### 3.1 *The Manuscript Tradition*

Apart from the two papyri of Leiden and Stockholm (late 3rd–early 4th century), all alchemical literature is saved in several Greek manuscripts. What follows here is the basic information regarding the most important manuscripts. The most ancient alchemical manuscript is Venice, Biblioteca Marciana, Marc. gr. 299 dated in the 10th–11th centuries. After a chronological gap of almost three centuries, there is Paris, Bibliothèque nationale de France, gr. 2325 dated in the 13th century. It follows a manuscript in Vatican, Biblioteca Apostolica Vaticana, Vat. gr. 1174 dated in the 14th–15th centuries. All other manuscripts date in the 15th century and later. There are three manuscripts accurately dated according to the date given by their scribes. Two manuscripts are in Paris, Bibliothèque nationale de France: gr. 2275 copied in 1465 by Emmanuel Roussotas and gr. 2327 copied in 1478 by Theodore Pelecanos. The third manuscript is in Florence, Biblioteca Laurentiana, Laur. gr. 86,16 copied in 1492 by Antonios Draganas.

In the 19th century, when M. Berthelot published his *Collection des anciens alchimistes grecs*, he did not make a critical edition of the texts. This interest was aroused in the last century and scholars began to study these manuscripts extensively. The most ancient manuscript Marc. gr. 299 aroused many questions regarding the identification of some texts because of a later transposition of its quires when it was rebound. As H.D. Saffrey pointed out, Berthelot observed the transposition of the quires Nos 13 and 14, and so he published their text in the right order, but he did not proceed further.[105] In 1995 M. Mertens in his critical edition of the "Authentic Memories" of Zosimos of Panopolis included a general study of the four manuscripts that contain his works, namely Marc. gr. 299, Par. gr. 2325, Par. gr. 2327, and Laur. gr. 86,16. She thinks that the source of the first part of Par. gr. 2327 is identical with Par. gr. 2325, and that Laur. gr. 86,16 is very close to Par. gr. 2327; but the solution of the problem of the relations between Marc. gr. 299 and the two manuscripts of Paris, gr. 2325 and 2327, would require their complete "collatio."[106] In 2011 M. Martelli published the critical edition of the alchemical works of Ps.-Democritos with the Commentary of Synesios, where he included his study of the same manuscripts. He made critical remarks on them and their tradition but did not give a definite

105 Saffrey, "Historique et description du manuscrit alchimique de Venise *Marcianus Graecus 299*," p. 3.

106 Mertens, *Zosime*, pp. xx–xliii generally on these manuscripts, and pp. xliii–lxxviii especially for the works of Zosimos, p. xlii.

answer because of many questions to be answered in order the problem of the manuscript tradition to be solved.[107] Finally, a significant study of Marc. gr. 299 by A. Roberts will be published in Dumbarton Oaks Papers 73 (2019).

### 3.2 *The Technical Background of Alchemy*

Alchemy as the art of transformation of base metals into gold or silver is closely related to metalworking techniques developed in antiquity and transmitted to Byzantium. From the hellenistic age on, the desire for luxuries extended into the lower social strata. As a result, there was an increased need for the production of luxury goods, albeit at moderate prices. Gold- and silversmiths sought techniques that would allow them successfully to make precious metal alloys and imitate precious and semiprecious stones. By the early 4th century, the papyri of Leiden and Stockholm include recipes that refer to various techniques for processing gold and silver.[108] There are recipes for "doubling," understood as a decrease in the degree of purity of an alloy of precious metal without a change in its colour, rather than a doubling of the mass of the metal itself. Other recipes refer to "dyeing," namely dipping hot metals into a cold liquid, usually water, to harden them.[109] Many others refer to making black silver,[110] gilding and silvering metal objects, methods for testing the purity of the metals, book illumination with gold and silver, the processing and imitation of precious and semiprecious stones, and the dyeing cloth.

Technical recipes found in Byzantine chemical codices dating from the 10th to the 15th century refer to the same branches of metalworking, especially to gold and silverwork.[111] The content of these codices is related to that of the papyri mentioned above. On this basis we can distinguish the following groups of recipes: a) the dyeing of copper and iron, the manufacture of dies, thin gold leaves, and so on; b) the cleaning of pearls and methods for making imitation pearls; c) the work of the goldsmith, especially refining (purifying) and welding gold and silver, illuminating books with gold and silver, and making wires.

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107 Martelli, *Ps.-Democrito*, pp. 3–54, 32,43, 54.

108 Leiden, Rijksmuseum van Oudheden, inv. I 397 (see Bidez/Cumont/Delatte, *Catalogue des manuscrits alchimiques grecs*, vol. 4, p. 381), Papyrus Leidensis X. Stockholm, Kongelige Biblioteket, Handskriftsavdelningen, Dep. 45 (see Bidez/Cumont/Delatte, *Catalogue des manuscrits alchimiques grecs*, vol. 4, p. 383) and Papyrus Holmiensis.

109 Homer (*Odyssey*, 9.391–3) describes the temper of iron so that it becomes steel. In the papyrus of Leiden there are recipes for temper of silver (*Fragmenta alchemica*, ed. R. Halleux, vol. 1, p. 99 § 65) and gold (pp. 102 § 78, 100 § 67).

110 Giumlia-Mair/Craddock, *Das schwarze Gold der Alchimisten*, 1993

111 *Alchemica*, ed. Berthelot/Ruelle, vol. 2, pp. 321–93.

In these texts, which are authentic sources for the materials and tools employed as well as the relevant techniques used up to the end of the 15th century, one may glimpse the effort of the craftsman to hide the secrets of his art, even when he seems to be revealing them! For this reason, although most recipes mention the general method of the work and the materials used, they omit the proportions of ingredients in various types of work; that is, they skip essential information for creating a metal object successfully. A basic technique was that of iron tempering,[112] that is, hardening it so that it becomes steel. In this recipe, we are given the proportions of the materials used for smearing over the point or edge of iron. An important distinction is made between the way of tempering (hardening) tools for stone carving, which does not need a sharp edge, and that for sharp knives and swords.

The *Suda* Lexicon (*c.* 11th century), states that χημεία is concerned with the making of gold and silver. Old books recording this process were burned by order of Diocletian (284–305).[113] The reason for this was probably connected to Diocletian's fiscal reforms, in which he also included the monetary system of Egypt. The striking of gold and silver coins with the image of the emperor was exclusively an imperial privilege, and those who encroached upon it were heavily punished.[114] For this reason a unique recipe in the oldest chemical codex in Venice, Bibliotheca Marciana, Marc. gr. 299 (10th–11th century), assumes great significance. It describes in detail the general method of making dies, that is, bronze moulds and reliefs for any coin.[115] This technique for making a die can be used for striking either a genuine or a false gold coin, depending on whether the work is done in the imperial mint or by counterfeiters. But, as the law against counterfeiting makes clear, the metalworkers of the imperial mints themselves were so involved in counterfeiting that they were considered as the main source of false coinage and were punished more severely than private persons.[116] If however, they struck coins themselves with tools stolen from the mint, and the coins possessed the appropriate legal composition and form, then the metalworkers were punished only for theft. In any case, the purpose of the law against hoarding old bronze coins was to reduce the metal available for making dies, which could then be used for forgery.[117]

112 *Alchemica*, ed. Berthelot/Ruelle, vol. 2, p. 342, line 20–p. 345, line 23.

113 *Suidae Lexicon*, ed. Adler, vol. 2, p. 104, s. v. Διοκλητιανός; vol. 4, p. 804, s. v. χημεία.

114 *Codex Theodosianus* 9.21–23. Grierson, "The Roman Law of Counterfeiting," 240–61. Hendy, *Byzantine Monetary Economy*, pp. 320–24.

115 *Alchemica*, ed. Berthelot/Ruelle, vol. 2, p. 375, line 9–p. 377, line 6; Papathanassiou, "Metallurgy and Metalworking Techniques," pp. 123–24.

116 Grierson, p. 254, note 3. *Alchemica*, ed. Berthelot/Ruelle, vol. 2, p. 239, line 12–p. 240, line 2.

117 *Grierson*, pp. 246, 252–53.

The importance of metalworking in Roman and Byzantine finances becomes evident in a significant text entitled *Differences of lead and goldleaf*.[118] This account book of a goldsmith's workshop mentions the raw materials and combustibles needed, as well as the productivity of the workshop, listed according to the daily production of its craftsmen, all specialists in various areas of gold work.

The texts extant in Byzantine manuscripts suggest that some techniques were influenced by those of Persia and India, evidently after the creation of the immense empire of Alexander the Great, while others betray Arab influence. These techniques were used not only for making weapons, tools, gold and silverware, and jewellery, but also for the decoration of various buildings (e.g., palaces and churches)[119] and manuscript illumination, especially with gold. The unbroken tradition of the technique of illumination becomes clear when we compare related recipes found in the Papyrus of Leiden, in Paris, Bibliothèque nationale de France, Paris. gr. 2327 (written in 1478), and in Dionysios of Fourna's *Manual of Christian Iconography* (written *c.* 1701–33) saved in two manuscripts dated in the 18th and the 19th century.[120] Dionysios' *Manual* saves "the proportions and the colours" used earlier by two great iconographers: Manuel Panselenos (early 14th century, Mount Athos) and Theophanes of Crete, who was active in the years 1527–59. Moreover, the fact that the iconographers of Mount Athos continued to use these old techniques provides evidence of the uninterrupted tradition of such techniques through the centuries. Based on the masterpieces of their technicians, Byzantine emperors rivalled Arab caliphs and Latin Kings for the luxury of their palaces. We may conclude that since antiquity the workshops of metalworking, especially in gold and silver, and the guilds of related artisans contributed both to the economy and to the political and cultural brilliancy of the states involved.

### 3.3 *Philosophy and Mystics in Alchemy*

In contrast to the artisans who knew that gilding and silvering affected only the surface of metals, while their interior remained unchanged, the philosophers basing their ideas on ancient theories regarding the structure and the quality of matter were firmly persuaded that it was possible to transmute base

118 *Alchemica*, ed. Berthelot/Ruelle, vol. 2, p. 377, line 7–p. 379, line 2; Papathanassiou, "Metallurgy and Metalworking Techniques," pp. 124–26.

119 *Alchemica*, ed. Berthelot/Ruelle, vol. 2, p. 37, lines 10–11.

120 Dionysios' recipe No. 72 (in Διονυσίου τοῦ ἐκ Φουρνᾶ, Ἑρμηνεία τῆς ζωγραφικῆς τέχνης, ed. Papadopoulos-Kerameus, 1909, p. 44) is the same with recipe No. 20 of Paris. gr. 2327 (*Alchemica*, ed. Berthelot/Ruelle, vol. 2, p. 327, lines 9–25), and with even earlier recipes of Papyrus of Leiden, pp. 97 § 51, 102 § 76, in Papathanassiou, "Χρυσογραφία," pp. 331–36.

metals into gold or silver. Aristotle's model of the four primary elements (fire, air, water, air) related to one another by the two pairs of opposite qualities (cold-warm, dry-humid) offered them a strong argument for their belief in transmutation. All things are composed of the four primary elements in various proportions. Consequently, if one can change these proportions in a base metal by heating, cooling, drying or humidifying it, a philosopher-alchemist might achieve its transmutation into gold or silver. The philosopher-alchemist believed firmly in the correctness of this theory, and the strength of the belief encouraged him to repeat many times the technical processes to attain his aim; any failure he attributed to his ignorance or to carelessness or to awkwardness.[121]

Generally, the works of earlier alchemists, e.g. Ostanes, Agathodaimon, Demokritos, and Zosimos (*c.* 300) are technical treatises on which later writers commented, e.g. Pelagios, Komarios, Synesios (not to be confused with Synesios the Bishop of Cyrene),[122] Olympiodore (6th century), and Stephanos of Alexandria (late 6th–early 7th century) while at the same time giving their own philosophical explanations. In later centuries the philosophers Michael Psellos (11th century) and Nikephoros Blemmydes (13th century), as well as a Christian writer, an anonymous philosopher, and a monk called Kosmas[123] composed treatises with technical instructions for the making of gold. Moreover, the so-called "μυστικὴ χημεία (mystical chemistry)" was based on Greek physical theories enriched with promises of redemption. The mystic philosopher tried to attain moral perfection permitting him access to the secrets of nature. Consequently, his numerous repetitions of the chemical processes were never effective in the creation of the "philosophers' stone" (or ξηρίον or elixir) unless he attained the highest degree of moral perfection.

Zosimos of Panopolis (province of ancient Thebes in Egypt) was a famous alchemist active *c.* 300. His technical treatises on furnaces and instruments used in alchemy, as well as treatises on its mystical aspects, are included among his *Authentic memories*. In his treatises *Περὶ ὀργάνων καὶ καμίνων γνήσια ὑπομνήματα* (*Authentic memories on instruments and furnaces*) and *Περὶ τοῦ ω στοιχείου* (*On the letter omega*), he refers to men who practice the art, but destiny was so great an influence on them that the success or the failure of their efforts depended on the favourable or the unfavourable aspects (angular distances) among the stars (planets). He says that Hermes Trismegistos called these men "silly/without understanding" (ἄνοες).[124] It is noteworthy that Zosi-

121 *Alchemica*, ed. Berthelot/Ruelle, vol. 2, p. 245, lines 18–24.

122 Martelli, *Ps.-Democrito*, p. 117, § 10.

123 Colinet, *Recettes alchimiques.*

124 Mertens, *Zosime*, pp. 2–3, § 4 (lines 34–40).

mos also refers to a work of Hermes Trismegistos where the latter rejects the use of magic and indicates how intellectual men could attain moral perfection and contemplate God. According to him, the intellectual man does not oppose Necessity, but accepts it and continues his way to self-knowledge and the knowledge of God. Having reached this level he does not care for his earthly body. The man who has trained his intellect and followed this way of living will contemplate God's Son who detaches the soul from Destiny's region and guides it to the incorporeal region. God's Son obeys the Father, penetrates any material body, illuminates the intellect of any soul and drives it towards the region of happiness where it once existed before the corporeal element came into being. The intellect follows it and influenced by it, is guided towards the light.[125]

Three centuries later Stephanos of Alexandria was invited by the emperor Herakleios to teach the *Quadrivium* in Constantinople. His work *De magna et sacra arte* (*On the great and sacred art; on the making of gold*)[126] written in 617[127] is saved in numerous manuscripts both in Greek and Latin dating up to the 19th century.[128] Some of these manuscripts belonged to high-ranking officers of the Church.[129] Stephanos praises all mighty wisdom[130] and defines philosophy as an assimilation to God, as much as it possible within the power of man.[131] He also states that the lessons of mathematics guide us from material things to immaterial ones, and from composite things to the simple ones.[132] Consequently, the "practical philosopher" devotes all his energy to realizing his ideal, in penetrating the secrets of nature, revealing them and participating in the

125 Mertens, *Zosime*, pp. 3–4, § 7 (lines 54–74).

126 Στεφάνου Ἀλεξανδρέως οἰκουμενικοῦ φιλοσόφου καὶ διδασκάλου τῆς μεγάλης καὶ ἱερᾶς ταύτης τέχνης περὶ χρυσοποιΐας, in Papathanassiou, *Stephanos von Alexandreia*, pp. 157–218 [Ideler, vol. 2, p. 199–p. 248, line 13].

127 Papathanassiou, "Stephanus of Alexandria: On the structure and date," pp. 258–64; idem. "Stephanos of Alexandria: A Famous Byzantine Scholar," pp. 180–88.

128 Papathanassiou, *Stephanos von Alexandreia*, pp. 61–81.

129 Papathanassiou, *Stephanos von Alexandreia*, p. 33: "Der älteste alchemistische Codex, Marcianus Gr. 299 (11. Jh.), gehörte dem Kardinal Bessarion; von den in Griechenland erhaltenen Handschriften gehörte der Cod. Bibl. Zagorae 58 ehemals dem ökumenischen Patriarchen Kallinikos IV. und der des Simon Karas dem ökumenischen Patriarchen Agathagelos (um die Wende zum 19. Jh.); weiter waren die Schreiber des Cod. Athen. Bibl. Senatus 126 und die des Cod. 8 im Kloster Zoodochou Pigis in Samos Hierodiakonen."

130 Papathanassiou, *Stephanos von Alexandreia*, pp. 95, 144, 200 (lecture VII, lines 34–36) [Ideler, vol. 2, p. 232, lines 13–15].

131 Papathanassiou, *Stephanos von Alexandreia*, pp. 94, 143, 188 (lecture VI, lines 34–35) [Ideler, vol. 2, p. 224, lines 27–28].

132 Papathanassiou, *Stephanos von Alexandreia*, pp. 144, 199 (lecture VII, lines 7–9) [Ideler, vol. 2, p. 231, lines 16–17].

creation of the world. As a practical philosopher Stephanos advises his audience about the proper way of living. He encourages his disciples to turn towards intellectual contemplation and to elevate their thoughts above matter; thus, having understood the glory of the angels they should not return to the vulgar practices of making gold. Instead they should pursue the principles of philosophy employing knowledge from the treatise they have in hand. Thus they should contemplate and admire the beauty of intellectual things, using the eyes of their intellect. Finally, they will come to understand God's sublime grace if and only if, having renounced the world and mortified their flesh, they might voluntarily wish for their deaths.[133] Stephanos may be influenced by Zosimos but, as an Orthodox Christian, he included prayers at the beginning and at the end of his lectures, where he refers to Jesus Christ and the three persons of the Holy Trinity.[134]

Stephanos repeats the principle of the unity of the world many times and states that the vital spirit is the active factor in chemical processes.[135] Apart from the known correspondences of the four primary elements (fire, air, water, earth) a) to the four cardinal points of the Zodiac (two equinoxes and two solstices), and b) to the four humours of the human body (yellow bile, blood, black bile, phlegm), Stephanos also introduces a correspondence related to chemical processes involving mercury, copper, their rusts, evaporated water. He also compares the changes of the colour of the seven planets moving in the Zodiac with the changes of colour of the compound observed during the process of making of the philosophers' stone.[136] He is openly opposed to "the illiterate technicians of metalworking who affirm that it is impossible to make gold, while they make it using numerous tools and instruments aiming at getting rich."[137] Influenced by Zosimos' work *On the letter omega* (cf. pp. 490–91), he also calls them as "devoid of understanding" as did Hermes Trismegistos. It seems that the poet-alchemists Archelaos, Heliodoros, Hierotheos, and

133 Papathanassiou, *Stephanos von Alexandreia*, pp. 142, 211–212 (lecture VIII, lines 127–129,136–137,141–142) [Ideler, vol. 2, p. 241, line 24–p. 242, line 6].

134 Papathanassiou, "Stéphanos d'Alexandrie : La tradition patristique."

135 Papathanassiou, *Stephanos von Alexandreia*, pp. 108, 144–45, 158–59 (lecture I, lines 38–39,41,77–78); p. 164 (lecture II, lines 111–112); p. 174 (lecture IV, lines 36f.) [Ideler, vol. 2, p. 210, lines 17f.].

136 Papathanassiou, *Stephanos von Alexandreia*, pp. 92–93, 147–48, 181–84 (lecture V, lines 27–89) [Ideler, vol. 2, pp. 220–22].

137 Papathanassiou, *Stephanos von Alexandreia*, pp. 95, 199–201 (lecture VII, lines 26–48,60–67) [Ideler, vol. 2, p. 232, lines 5–30, p. 233, lines 6–15].

Theophrastos belonged to Stephanos' close environment including his disciples; so their poems were strongly influenced by his lectures.[138]

Stephanos was the last Alexandrian commentator before Alexandria's fall to the Arabs (641) and his name is closely linked with the transmission of Greek alchemy to them. According to the Latin-Arab tradition, a monk called Morienus had been one of Stephanos' students was also the first who taught the secrets of the great and sacred art of the chrysopoeia (making of gold) to the Arab prince Hālid ibn Yazīd.[139] But, if we take into account the dates of Yazīd and his son, it is clear that Morienus could not have been a student of Stephanos. According to F. Sezgin, the authorship of the alchemical work attributed to Stephanos in the Arabic tradition is a complicated one, because there exist various works of two alchemists with the same name, Stephanos. One is included in the catalogue of alchemists made by Hālid ibn Yazīd, and the other is a monk from Mosul at the turn of the 10th century. J. Ruska states that Iṣṭafan al-Qadīm, mentioned by Ibn an-Nadīm as the translator of books for Hālid ibn Yazīd, is not a historical person; his name is only a remembrance of Stephanos, court astrologer and alchemist of the emperor Herakleios. The critical question is, whether it was possible that Stephanos of Alexandria could have been invited by Hālid from Constantinople to Damascus to translate these books for him. We should remember that when Yazīd died less than 40 years old on 11 November 683, his young son Hālid would have been 15 or 16 years old. As Merwan, the new Caliph and Hālid's step-father (who died in 685), proclaimed his son Abd al-Malik as his successor, there is no doubt that Hālid abdicated and consecrated his life to science until his death in 704. But in 685, when Abd al-Malik became Caliph, Stephanos would have been 120 years old! Consequently, J. Ruska is correct.[140]

Stephanos lectured at least once in the presence of the emperor Herakleios,[141] but it is unknown whether the latter was more interested in the philosophical rather than the practical aspects of alchemy. More than a century later, the emperor Constantine V Kopronymos (741–75) himself practiced the techniques of silvering and gilding base metals. It was famously recorded that he astonished al-Manṣūr's ambassador ʿUmāra ibn Ḥamza during his visit to the Byzantine court, when he made an experiment of making gold:

138 Ideler, vol. 2, pp. 328–35 Theophrastos, 336–42 Hierotheos, 343–52 Archelaos. Also in Goldschmidt, *Heliodori carmina quattuor*, pp. 26–34 (Heliodoros), 34–42 (Theophrastos), 42–49 (Hierotheos), 50–59 (Archelaos). Papathanassiou, "The poet-alchemists."

139 Stavenhagen, *A Testament of Alchemy*.

140 See also Papathanassiou, *Stephanos von Alexandreia*, pp. 59–60.

141 Papathanassiou, *Stephanos von Alexandreia*, p. 213 (title) [Ideler, vol. 2, p. 243, lines 1–3].

> Another day Constantine invited him to a particular building apparently outside the imperial palace. There were rooms with sealed doors. One of them was opened and ʿUmāra saw piled up bags filled with a white powder. Constantine asked him to point at random at one bag, and a small amount of it was taken into a vessel. Another sealed room contained bags with a red powder, and ʿUmāra was asked again to choose the bag from which the sample was taken. Then the emperor ordered a portable furnace to be brought together with ingots of lead and copper. First, the lead was melted, and a tiny amount of the white powder just covering a thumbnail was sprinkled over the metal. The result was pure silver. The same was done with the copper and the red powder, and "red gold" flowed out of the furnace. Constantine concluded with the remark: "Your lord should know that this is my money." ʿUmāra adds: "I reported this to al-Manṣūr, and this was the reason that induced him to become concerned in alchemy."[142]

As G. Strohmaier remarks,

> We have in ʿUmāra's account the earliest Arabic testimony for the whole concept of transmutation with the help of the elixir, hitherto unnoticed in the history of science, so far as I know. And here we recognize all the basic principles which dominated the efforts of the Muslim alchemists later on: 1) the idea that the elixir should be a dry powder, in correspondence with the Greek term "xerion" whence the Arabic *al-iksīr*. The latter does not occur in the preserved parts of ʿUmāra's report. 2) The distinction between a red elixir for gold and a white elixir for silver. 3) The relation between a tiny amount of the elixir and the quantity of the base metal up to more than a million times larger. 4) The expectation that the elixir acts instantly by simple "projection."[143]

The same attitude towards the practical application of alchemy is attested to in the mid-eleventh century when Michael Psellos wrote his treatise *Περὶ τοῦ ὅπως ποιητέον χρυσόν* (*On the making of gold*) in the form of a letter addressed to Patriarch Michael Keroularios (1043–58). It was the Patriarch himself who had asked Psellos to investigate the ancient methods of chrysopoeia. As is clear from Psellos' Letter, Michael Keroularios was not interested in philosophical theories but rather in practical applications of alchemical methods. Thus Psellos was obliged to restrict his theoretical inquiries to a lengthy introduction and

142 Strohmaier, "ʿUmāra," p. 22. Strohmaier, "Al-Manṣūr," p. 170.

143 Strohmaier, "ʿUmāra," p. 23.

focus on the art of fire or the art of transformation. The latter included practices and techniques dealing with the transformation of various materials, and especially their transmutation into gold:

> Since in my preface I have already insisted enough on the fact that transformations of matter happen according to natural changes, and not using magic spells, miracles, or some other secret practice (so, we must not wonder), it is time to pass on to this art of transformation. I would have liked to compose a complete discourse on this art and how to work the matters [...] However, since you [Michael Ceroularius] do not allow me to delay with such superfluous inquiries, wasting all my studiousness in a worthless research, but you want me to examine with which substances and according to which scientific method gold may be produced, I am going to explain only this topic.[144]

Two centuries later, Nikephoros Blemmydes wrote his technical treatise *Περὶ τῆς ᾠοχρυσοποιΐας* (*On the making of gold*).[145] The work *Ἑρμηνεία τῆς ἐπιστήμης τῆς χρυσοποιΐας* (*Interpretation of the science of making gold*) of a monk called Kosmas[146] is another technical treatise preserved from the Palaiologan period.

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In the limited space of this chapter, we have attempted a general description of the most representative aspects of "occult sciences" in the Byzantine period. Our references to selected passages of the works of the Fathers of the Church as well as to early and late Byzantine scholars who recorded various magical rituals practiced during their time and even by members of the royal family or high-ranking state and ecclesiastic officers offer proof that the occult sciences survived through the centuries. We should not be surprised by this, since such practices appeal to the irrational rather than to the rational part of man. Moreover, man's anxiety to know his future and, if possible, to change it through mysterious methods and supernatural forces, may explain his strong attraction to them.

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144 Psellos, *Épitre sur la Chrysopée*, in Bidez/Cumont/Delatte, *Catalogue des manuscrits alchimiques grecs*, vol. 6, p. 30, line 16–p. 31, line 9. Martelli, "The Alchemical Art of Dyeing," p. 2.

145 Blemmydes, *Περὶ τῆς ᾠοχρυσοποιΐας*, in *Alchemica*, ed. Berthelot/Ruelle, vol. 2, pp. 452–59.

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# Conclusion

*Anne Tihon*

When I agreed to write a conclusion to this *Companion to Byzantine Science*, I took on a perilous task. Each chapter of this book indeed contains an impressive amount of erudition, and each topic treated here would deserve in itself one or more separate volumes. However, reading the different chapters, a first remark comes to mind: it is time to stop apologizing for using the word "science" when studying Byzantine civilisation. The word "science" may cover many different activities: study, teaching, creating manuals, commenting on scientific treatises, applying ancient or modern methods, conducting research, experiments and so on. There is no doubt that all the activities described in this volume fall into at least one of these categories.

In spite of some received ideas, the Byzantine world was open to all kinds of intellectual activity, and especially to the scientific legacy from antiquity. This consists of a considerable number of writings which laid the foundation of science in the modern meaning of the word: Euclid, Apollonius, Archimedes, Diophantus, Ptolemy, Hippocrates, Galen, Dioscorides, including many more elementary treatises such as Autolycus, Theodosius, Geminus, Cleomedes and others. Everybody agrees that the Byzantines preserved this legacy; but they did much more than simply preserve it: they kept it alive. Some Byzantine scholars undertook considerable work in understanding and practising, for example, the astronomical exercises and calculations of Ptolemy. It is almost a common topic amongst Byzantine texts to complain about the headache resulting from such study; and the funeral eulogy of Bessarion asserts that the study of astronomy in his youth seriously compromised his health! The study of Euclid's geometry never ceased as Anna Komnena recalls through the story of a man who, after being blinded, studied Euclid with help of figures in relief. Other scholars suffered a great deal for Diophantus' problems. Without the continuous efforts of Byzantine scholars to understand, explain, edit, apply, comment or paraphrase the ancient treatises, these works would have become incomprehensible or would have simply disappeared.

In spite of its importance, ancient heritage was not the only source of Byzantine scientific knowledge. The Byzantine empire, which during some periods covered an extensive geographical area, was not closed in on itself. Whether in astronomy, mathematics, medicine, botany, or in what we call today 'pseudo-sciences' such as astrology, alchemy, magic, in Constantinople as well as in

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other important towns, such as Thessalonica or Trebizond, or in neighbouring provinces, foreign influences clearly appear in Byzantine texts. The exchanges between Byzantium and the Arabic and Persian worlds, Western countries or Jewish communities, were intense and favoured by various circumstances: the Byzantine Court always welcomed many foreigners; merchants, medical practitioners, veterinarians, travellers also brought with them many kinds of practical procedures or various types of knowledge.

At the end of antiquity, in the 5th and 6th centuries, the late Hellenic schools of the Eastern Roman Empire (Alexandria, Antioch, Apamea, Athens, Rhodos…) played a major part in the transmission of Greek sciences into Syria, Armenia or Persia. Syrian texts of the 5th and 6th centuries testify the diffusion of Ptolemy's astronomy to Mesopotamian monasteries: one needs only recall here the name of Severe Sebokht (7th *c.*).

The transmission of Greek science into the Arabic world through the agency of Byzantine manuscripts cannot be explored here, but I would just like to mention an interesting document: the palimpsest *Vaticanus syriacus* 623. This manuscript contains edifying stories written in Syria in 886 on palimpsest folios of parchment. The inferior writing shows some of Ptolemy's astronomical tables (Πρόχειροι κανόνες) written in uncial script dating from the early 9th century; on other folios one can read an Arabic translation of Theon's *Small commentary*. Some words in the Arabic translation are written in Greek by the same hand as the tables, and one of the Greek astronomical tables contains a Greco-Arabic lexicon with the names of the winds. The document was probably written in St Catherine's monastery of Sinai. Thus at the border of the Byzantine Empire, in a multi-cultural milieu, we can see an attempt to translate and pass on in Arabic Ptolemy's astronomical tables. This is perhaps one of the most ancient witnesses of this process.

During the Palaiologan period, in the 13th century, Persian astronomical tables were introduced into Byzantine culture through Trebizond. The Persian tables, of the *Zīj-i Ilkhānī,* adapted by George Chrysococces around 1347, were immediately widely diffused. One can find various adaptations of these tables in Constantinople, Cyprus, Rhodes, Mitylenos, Nicaea, and a Latin adaptation in Candia (Crete). In the 15th century, the Byzantine version of Persian tables were translated into Hebrew in the Jewish communities of Constantinople or Thessalonica. Moreover, several Jewish astronomical treatises composed in Provence, in Spain or in Italy were translated in Greek in Constantinople where they were widely diffused.

At the end of the Byzantine Empire, many people travelled in European and Slavic countries, in Turkey, but also to the Near and Middle East: diplomats, scholars, members of the high clergy carried with them manuscripts, note-

books and knowledge. The manuscripts from the end of the 14th century and the 15th century carry evidence of a very complex network of intellectual exchange. Mystra was adorned by the preeminent individual George Gemistus Plethon and became an intellectual centre, which attracted many visitors.

The reader will forgive me if I have chosen my examples from the field of astronomy, but many other examples can be found in other fields of science: arithmetic, medicine, botany, pharmacology… One can mention for example the gift by Emperor Romanos II (953–962) of a manuscript of Dioscorides to the Caliph of Cordoba; or the gift by Manuel Comnenos of a manuscript of Ptolemy's *Almagest* (*Marcianus gr.* 313) to the Norman king William I of Sicily. It is one of the most fascinating studies for an historian to retrace the routes of this scientific transmission.

In this *Companion*, one finds chapters devoted to the sciences of the *Quadrivium*, where the boundaries were precisely defined: arithmetic, geometry, astronomy, music (or Harmonic). These are illustrated by numerous treatises or manuals, written by either well known or unknown authors, but also through the many notes, isolated calculations, marginal remarks, scholia left in the manuscripts. But this volume is also noticeable for a great number of chapters devoted to many disciplines which are not associated with the traditional *Quadrivium*: optics, mechanics, physics, geography, botany, zoology, meteorology, medicine, pharmacology, veterinary science, military technique, occult sciences… These are fields especially difficult to explore, because the sources are extremely disparate and unpredictable. Meteorology derives mainly from Aristotle and from his Alexandrian commentators, but the historian must add many anonymous compilations which collect summary explanations about phenomena such as winds, rain, thunder, earthquakes, rainbows, the Milky Way, comets…; or astrological texts which give various predictions or explanations of such phenomena. And also historical chronicles in which some natural disaster is associated with celestial configurations such as the appearance of a comet or the occurrence of an eclipse. Another difficult topic is geography, which may take many forms: cartography, description of countries, administrative lists, peripleia, itineraries, description of the world, Biblical, astrological or mythical geography, isolated diagrams or maps, lists of famous cities included in the astronomical tables (Greek, Persian, or Jewish). In the manuscripts of the 14th and 15th centuries, one finds notes correcting the latitude of a town, perhaps as the result of personal measurements. Medicine, pharmacology, botany, zoology, and veterinary medicine are rooted in the traditional antique sources, but may be considerably enlarged by foreign influence, or simply by oral transmission which is impossible to determine. It is obvious that the medical care of humans or animals, the preparation of drugs or medicine could not be only a

matter of books but must be acquired by practice under the supervision of an experienced master. Occult sciences, astrology, alchemy, magic, hermetic also offer a wide field of research, in which crossing influences are difficult to retrace. This part of Byzantine civilization deserves to be better known, and one must be grateful to the courageous authors of the chapters devoted to these complex matters.

In this volume, the cultural and religious context, the origin and development of the specific Byzantine mentality, is explained in Ch. 1. The idea that the influence of Christianity was very damaging for the development of scientific research cannot be supported here. Indeed, if there was some opposition to the study of pagan sciences at the beginning of the Byzantine Empire, the conflict was rapidly overcome and even some specific religious questions, such as the date of Easter, became a powerful stimulus to promote the astronomical study in the clerical milieu.

It could also be enlightening to draw our attention to the question of language, a question which was perhaps not discussed enough here. Most of the treatises concerning a 'noble' science, *i.e.* a science of the *Quadrivium*, are written in learned Greek, imitated from the ancient classical Greek. In the other fields, especially in more pragmatic matters (botany, medical recipes, and similar), texts are written in a vernacular language, the spelling in the manuscripts being quite arbitrary.' Sometimes, the language is characteristic of a specific part of the Byzantine world, such as the treatise on alchemy, the *Anonymous treatise of Zuretti*, written in a Greek characteristic of South Italy. The level of language gives precious indications about the author, the milieu in which he wrote, and the alleged readership.

The material support, which allowed the diffusion of knowledge, must also be considered. In recent years, significant progress has been made in Greek palaeography and codicology. These studies make it possible to identify many hands especially in the most prolific Palaiologan period. Therefore, it is often possible to find the autograph, to discover the author of some anonymous text, or the intellectual circle in which a text was composed or copied. The material itself (papyrus, parchment, paper) is important, as preserved papyrus, from the Byzantine period can, for instance, provide important information in some fields such as arithmetic, botany, medicine, veterinary science, magic… The numerous and verbose scholia coming from the late school of Alexandria in the 5th and 6th centuries are witnesses of a milieu where papyrus was cheap and abundant. On the contrary, the luxurious manuscripts on parchment copied in the 9th century could only have been accessible to a select group of readers. Hence, were these books really read or were they copied only for the sake of preservation? The growth of writings at the end of 13th century and up to the

end of the Byzantine Empire coincides with the massive introduction of paper, again a cheap material which allowed everybody to get his own copy or notebook. In some matters, non-literary sources have to be employed, such as medical instruments, mosaics or various representations, illustrations in the manuscripts, or, for botany, hints of plants or cereals found in archaeological excavations. Unfortunately, almost no scientific instruments have been preserved, except the Brescia astrolabe, an instrument dated from 1062 made for an officer of Persian origin. This lack is partly compensated by treatises carefully explaining how to draw the different parts of the instrument. The automata, clocks (except some Sundials), celestial spheres, war machines, alchemical equipment have all disappeared, but in some cases the figures in the manuscripts give an idea of their construction. The history of technology in the Byzantine world still remains to be written.

One topic which cannot be neglected today is the part played by women in this long story. And if it does not seem right to expect to see women taking a major role in the history of Byzantine science, they were not absent. One may think for example that women played an important part in medicine, especially in gynaecology and obstetrics. The Byzantine woman was certainly far from ignorant as she ensured the initial education of her children: reading, writing, counting. A girl was not allowed to attend a public school, but she could receive a careful education at home with a private tutor, generally an old man or an eunuch. The case of Princess Anna Komnena is well known: she studied philosophy—as far as it was allowed to a Christian—and the *Quadrivium* of science with help of a eunuch of the palace, unbeknownst to her parents. Later, during her enforced retirement, she encouraged Michael of Ephesus to comment on the zoology of Aristotle. Constantine Acropolites (13th–14th C.) corresponded with a distinguished woman about an astrological treatise. In her last days, the Empress Zoe (reigned 1028–50) spent much time in her apartment preparing ointments and perfumes with aromatic plants coming from all parts of the world.

Some twenty-five years ago, when I proposed to the publisher of *Variorum Studies* to reprint a collection of articles dealing with Byzantine astronomy, I received a reply saying: "Who is interested in Byzantine Astronomy? Perhaps on the whole eight persons?". On my insistence, the volume was published. At that time, Byzantinists were not interested in scientific fields and the international congresses of Byzantine Studies never included a section on science. My colleagues who were historians of Arabic science, were much more open to Byzantine scientific texts, because they realized the importance of the Byzantine sources for a better knowledge of Arabic and Persian science. The situation

has changed now, and this volume is a brilliant demonstration of the interest in Byzantine scientific achievement.

Much work remains to be done for a just understanding of Byzantine science. The first task is to edit the sources following a few principles such as the importance of good critical editions. These should not be hastily compiled works but the fruit of the thorough examination of all the manuscripts—not just an arbitrary selection based on opportunity or chance. The editions should also be produced with good translations since the time has long gone when an *honnête homme* was supposed to know Greek and Latin! The translation must be faithful, and not consist of a rough paraphrase, which disfigures the Greek text. A detailed analysis of the document is important: what could we say about the calculations of John Chortasmenos so elegantly written, but full of errors? These can be realised only if the author's procedure is followed step by step.

The difficulty of such a task might arise from the tricks used by the Byzantine authors themselves such as the common topic or the literary convention. When a Byzantine scholar asserts that his calculation conforms to observation, it does not mean that he made such an observation: he is just imitating Theon. The Byzantine author will declare that he is the first to treat some topic, while he is shamelessly pillaging the work of his predecessors. Theodore Metochites or Theodore Meliteniotes for example quote with great complacency the ancient writers, but almost never their Byzantine predecessors. What can be said about the staging of a show in which the author plays the principal role, like Nicephorus Gregoras explaining the question of Easter in the presence of the Emperor Andronicus II and of the whole imperial court? Or publicly defeating his rival, Barlaam of Calabria? Gregoras himself tells us that the Emperor did not dare to reform the Canon of Easter, for fear of troubles in the Church, while Isaac Argyros says that the reform proposed by Gregoras was accepted with enthusiasm… Again, what do we make of the tale of George Chrysococces showing Chioniades struggling to be allowed by the Persian Khan to study astronomy 'reserved to Persians only' while other sources show the observatory of Maragha receiving many foreign students from East and West? It is just a way of exalting the subject. Such tales are probably fictitious or, as Marcel Pagnol so nicely said: "la vérité en habits de fête"!

There is much more to be said about this volume. There is no doubt that many points will be raised in discussion or criticism, but everybody will acknowledge the difficulty of the challenge and applaud the efforts of the scientific editor, Stavros Lazaris, and his collaborators.

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*Note to the reader*: The names of ancient, Byzantine, and medieval authors, and the titles of their works are mentioned in the Bibliography in the form they have in the *Thesaurus Linguae Graecae* (TLG) and the *Library of Latin Texts* (LLT), accordingly. Since Brill's *Companions* are intended for both a specialized and a wider audience, the names of the authors in the essays of the present *Companion* follow *The Oxford Dictionary of Byzantium* and/or *The Oxford Classical Dictionary*. When different, the two forms of authors' names are listed in the index of ancient and medieval authors and are cross-referenced. Under the heading "Paul of Aegina," for example, readers will find: "Paul of Aegina (see Paulus Aegineta)" and, conversely, under the heading "Paulus Aegineta," they will find "Paulus Aegineta (= Paul of Aegina)".

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# Indices

*Antonio Ricciardetto*

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